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A TEXT BOOK OF

FILTRATION

Industrial Filtration and the Various Types of Filters Used

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WITH TWO HUNDRED AND SIXTY-FOUR ILLUSTRATIONS

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PREFACE

The great dirth of filtration literature has been due, in the past, largely to the lack of attention paid to filtering by scientists. Until the comparatively recent advent of modern filtering apparatus no attempt was made to treat the separation of solids from liquids in anything like a scientific manner, or to carry on experiments extensive enough to give data of any worth. Ordinary drainage boards, sand filters, false-bottomed tanks, and later the plate and frame press were considered as the only means of getting results and if the materials could not be handled by such apparatus, either the process was changed to meet the requirements or it was abandoned altogether.

To-day, although a great deal of work has been done in scientific filtration and a large number of new filters developed, only a beginning has been made and available data is far from complete. A number of miscellaneous pamphlets and articles have been published from time to time but with the exception of one or two books published abroad which are neither complete nor up to-date and a recent publication in France by Leoncé Fabre (La Separation Industrielle des Solides En Milieu Liquids) no attempt has heretofore been made to produce a text covering the subject.

As filtration is of such importance there is need primarily of a text-book giving the fundamental principles underlying filtration, the modifications necessary under varying conditions, the proper procedure for carrying on experiments, the available data on filtration, and a description of the various types of filters which have been developed as a result of scientific research. It is with this end in view and the desire to collect under one cover all pertinent filtration information that this volume is attempted.

April 1, 1923.

CONTENTS

PAGE

CHAPTER I

Principles of Filtration 1

CHAPTER II

History of Filtration 26

CHAPTER III

Dewaterers, Expellers, False-Bottom Tanks and Classifiers 35

CHAPTER IV

Water Filters, Gravity and Pressure 55

CHAPTER V

Centrifugal Machines 96

CHAPTER VI

Air, Gas and Light Filters 121

CHAPTER VII

Hydraulic Presses 140

CHAPTER VIII

Oil Filters, Oil Extractors and Oil Expellers 166

CHAPTER IX

Laboratory Filters and Special Apparatus 187

CHAPTER X

Plate and Frame Presses 207

CHAPTER XI

Leaf Filters 225

CHAPTER XII

Rotary Filters 254

CHAPTER XIII

Coagulants and Filter-Aids 282

CHAPTER XIV

Filter Media 292

CHAPTER XV

Operating Data and Care of Apparatus 301

CHAPTER XVI

Auxiliary Equipment 331

APPENDIX

Useful Information in Charts and Tables 357

Index of Subjects Treated 373

LIST OF ILLUSTRATIONS

FIG. PAGE
1. Section of Filter Medium . . . 2
2. Surface View of Particles . . . 3
3. Layers of Particles . . . 4
4-5. Rhombic Particles . . . 7
6-7. Pressure Curves . . . 10
8-19. Photomicrographs of Precipitates . . . 14
20-31. Photomicrographs of Precipitates . . . 16
32. Bird Save-All . . . 36
33. Bird Save-All (Section) . . . 37
34. Oliver Sand Table . . . 38
35. Wood's Machine . . . 40
36. Rotary Hopper Dewaterer . . . 41
37. Continuous Screw Press . . . 43
38. Continuous Screw Press Showing Adjustable Cone . . . 44
39. Anderson Moisture Expeller . . . 46
40. Louisville Filtering Machine . . . 47
41. Continuous Moisture Expeller . . . 48
42. Suction Stone Ware Filter . . . 50
43. Gravity Stone Ware Filter . . . 51
44. Dorr Classifier . . . 51
45. Dorr Bowl Classifier . . . 52
46. Interior View of a Filter Unit Showing Wash Troughs and Air and Water Manifolds. Sand Bed Not Yet in Place 57
47. The Hodkinson Wood Tank, Open Gravity Filter . . . 58
48. Vertical Type, Steel Tank, Pressure Filter . . . 59
49. Sectional View of Horizontal Pressure Filter . . . 60
50. Strainer or Sand Valve . . . 61
51. Blackburn-Smith Feed Water Filter . . . 62
52. Blackburn-Smith Feed Water Filter . . . 65
53. Blackburn-Smith Filter Cartridge . . . 66
54. Cummings Filter "D" . . . 68
55. Cummings Manipulator . . . 69
56. Cummings Filter (Section) . . . 70
57. Cummings Filter "H" . . . 71
58. Cummings Filter—Style "G" . . . 72
59. Sand Valve . . . 73
60. Sectional View International Filter . . . 75
61. Disc Filter . . . 76

FIG. PAGE

62. Filter Discs 77
63. New York Sectional Wash Filter 78
64. Jewell Gravity Filter 80
65. Warren Gravity Filter 81
66. New York House Filter 82
67. New York Sectional Wash Filter 83
68. Jewell Filter 83
69. Lime and Soda Water Softener 85
70. Pittsburgh Gravity Filter 86
71. Strainer 87
72. Horizontal Pressure Filter 88
73. Keystone Pressure Filter 89
74. Vertical Pressure Filter 90
75. Permutit System 91
76. Refinite Water Softener 92
77. Bottom Section of Container Showing Soft Water Collector System 93
78. Driving Mechanism—De Laval Centrifuge 98
79. De Laval Centrifugal (Section) 99
80. De Laval Centrifugal 100
81. De Laval Bowl Clarifier (Section) 101
82. Filter Bowl—De Laval Centrifugal 102
83. Elmore Centrifugal 104
84-85 Distributing Cone and Screen Basket 105
86. Resines Centrifugal Separator 107
87. Piece Goods Extractor 109
88. Textile Extractor 110
89. Sharples Super-Centrifuge 111
90. Sharples Clarifier 113
91. The Process of Centrifugal Separation 115
92. Centrifugal 117
93. Centrifugal Machine (Section) 118
94. Center Slung Centrifuge 119
95. By-Products Dust Collector 123
96. Taylor-Milliken Dust Collector 124
97. Clark Dust Collecting System 127
98. Dust Collecting System 128
99. A. B. C. Filter Disc 128
100. Expanded Metal Screen 129
101. A. B. C. Air Filter 130
102. Eliminator Unit 131
103. Natural Humidifier 132
104. Desk Cooler 134

FIG. PAGE
105. Air Washer 135
106. Dust Collector 136
107. Oil Separator 136
108. Zenith Dust Collector 137
109. Screw Press 141
110. Knuckle Joint Press 142
111. Hydraulic Press (Upward Pressure) 143
112. Hydraulic Press (Downward Pressure) 144
113. Rack 145
114. Double Rack 145
115. Building "Cheese" for Hydraulic Press 146
116. Worthington Filter—Filling 147
117. Worthington Filter—Pressing 148
118. Worthington Filter—Dumping 149
119. Platen 150
120 Metal Bag 151
121. Corrugated Rack 153
122. Box Press 155
123. Steel Press Boxes 156
124. Hydraulic Olive Oil Press 157
125. Cage Press 158
126 Pot Presses, Parts 1-2 160
127. Pot Press 161
128. Curb Press 163
129. Curb Press 164
130. American Oil Filter 167
131. Burt Unit Filter 169
132. Burt Automatic Water Separator 170
133. Cross Oil Filter 170
134. Warden Oil Filter 171
135. Daisy Oil Filter 172
136. Erie Oil Filter 173
137. Parts—Erie Oil Filter 175
138. Ross Oil Filter 176
139. Sims Oil Filter 178
140. American H_2O Grease Extractor 180
141. Anderson Steam and Oil Separator 181
142. Oleite Oil Filter 183
143. Anderson Expeller 185
144. Buchner Filter 188
145. Funnel Filter 188
146. Gooch Filter 188
147. Alundum Cone 188

FIG. PAGE
148-149 Porcelain Filters 189
150 Bergfeld Filter 189
151. Tincture Filter 190
152. Gas Filter 190
153. Laboratory Centrifuge 190
154. Laboratory Plate and Frame Filter 191
155. Laboratory Rotary Filter 192
156. Vallez Experimental Filter 193
157. Laboratory Open Tank Filter 195
158 Labortory Plate and Frame Filter 196
159. Bag Filters 202
160 Bag Filters—Cylindrical Type . . 202
161. Karl Kiefer Filter 204
162 Karl Kiefer Filter 204
163. Tray Filter 205
164. Round Plate and Frame Filter . . . 208
165. Square Plate and Frame Filter 209
166. Square Plate 209
167. Round Plate 209
168. Plate 210
169. Plate and Frame Filter 211
170 Plate and Frame Filter 212
171. Plate and Frame Filter 212
172. Plate and Frame Filter . . 213
173. Plate and Frame Filter 213
174. Plate 214
175. Triangular Plate and Frame Press 215
176. Triangular Filter Frame 215
177. Triangular Filter Plate 216
178. Perrin Filter 217
179. Perrin Filter—(Section) 218
180. Wooden Plate and Frame Filter 219
181. Wooden Plate and Frame 220
182. Cross Section—Recessed Plate Press 221
183-184. Cross Sections—Flush Plate and Frame Press . 221
185. Dummy Plate 222
186. Hydraulic Plate and Frame Press 222
187. Switch Cock 223
188. Buflovak Filter (Section) 226
189. Buflovak Filter 226
190. Burt Filter—End Elevation 227
191. Burt Filter—Side Elevation 228
192. Burt Filter 231

FIG. PAGE
193. Burt Locking Mechanism . 232
194. Philippe Filter (Section) 235
195. Philippe Filter 236
196. Kelly Filter 239
197. Kelly Filter . 240
198. Sweetland Filter . .. 243
199. Sweetland Filter (Section) . 244
200. Vallez Rotary Filter 247
201. Vallez Rotary Filter . 248
202. Filter Leaf 251
203. Open Tank Filters . 252
204. American Continuous Filter . 255
205. Filter Disc—American Continuous Filter 256
206. Valve—American Continuous Filter . 258
207. Filtros Wheel 260
208 Filtros Wheel . 261
209 Filtros Wheel 263
210. Glamorgan Rotary Filter . .. 264
211. Oliver Continuous Filter 266
212. Oliver Continuous Filter (Section) . .. 267
213. Valve—Oliver Continuous Filter 269
214. Portland Continuous Filter 270
215. Valve—Portland Continuous Filter 271
216. Portland Continuous Filter—Showing Construction . 272
217. Zenith Rotary Filter 275
218. Zenith Rotary Filter . . 276
219. Zenith Filter (Section) 278
220. Pressure Roller Unit 279
221. Bacteria in Water 282
222. Coagulation of Water . 283
223. Paper Pulp Cake—Vallez Rotary Filter . .. 289
224. Filter-Cel Matrix 290
225 Methods of Supporting Filter Cloth 297
226. Filtering-Rate of Slime for Three Types of Filters . . 298
227. Growth of Water Filtration in United States 302
228. Heat Loss Due to Scale 303
229. Wash Curves 320
230. Open Tank Filter Curve 324
231. Wash Curves 324
232. Average Filtering-Rates for Slime-Cakes, No. 10 Canvas .. 325
233. Effect of Variation of Pressure upon Filtering-Rates, No. 10 Canvas 325
234. Rotary Vacuum Filter Curve 327

FIG. PAGE

235. Rate of Building up Cakes No. 12 Duck . 329
236. Rate of Building up Slime-Cakes 329
237. Filtration Curves . . 330
238. Coagulation Feeder 331
239-240. Coagulant Feeds . . 332
241. Coagulator Feeder 333
242. Coagulation and Aerating System 334
243. Details of Norristown Aerator—Receiving Chamber and Aërator 335
244. Centrifugal Feeding Device . 336
245. Dorr Thickener 337
246. Dorrco Pump 339
247. Vertical Triplex Pump 341
248. Duplex Steam Pump . . 341
249. Mounted Filter Press Pump . 342
250. Filter Press Pump 343
251. Centrifugal Pump 344
252. Pyramid Wet Vacuum Pump 344
253. Dry Vacuum Pump 345
254. Dry Vacuum Pump . 345
255. Dry Vacuum Pump . . 346
256. Connecting Rod . 346
257. Rotary Pump . . 347
258. Hydro-turbine Pump . 347
259. Sectional View of Compressor 348
260. Air Compressor 349
261. Manguin Filter Cloth Washer 350
262. Paper Pulp Washer . 351
263. Mixing Tank 354
264. Rotary Filter with Repulping Tank 355

CHAPTER XIII

COAGULANTS AND FILTER AIDS

The most important use of coagulants is to enable water filtration to free impure water from polution so that it is fit for drinking purposes. There should be borne in mind the fact that typhoid fever, an entirely preventable disease, is always caused by taking the typhoid germ in the mouth and therefore to eradicate the disease it is practically only necessary to have pure food and drink. When it is remembered that in the United States up to the year 1914 over one-half the deaths which occurred between the ages of ten and fifty were due to typhoid fever some idea of the vital importance of pure water for the prevention of this disease alone is realized. In addition to this it is estimated that impure water really causes ten times as many complaints other than typhoid.

All public water supplies should be efficiently filtered, even though sewage treatment is carried on by large communities as this only aids in the general sanitation and does not greatly improve the hygienic quality of the water supply. For years it has been recognized that immediately following the installation of efficient water filters for municipal water supply the death rate of typhoid is reduced to from one-third to one-quarter of the original figures and therefore the cost of installation or maintenance should never be allowed to stand in the way, if a city or town is being supplied with unfiltered water. A marked illustration of the reduction of the bacterial content by filtration is shown in Figure 221.

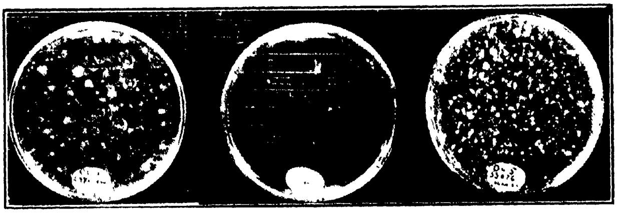


Fig. 221

A coagulant is a harmless chemical which when added in minute quantities to a liquid produces a gelatinous precipitate that envelopes the mud, clay, organic matter, and bacteria, and causes them to form into aggregates of such size that they can be much more easily removed, either by sedimentation or by filtration than in the case of uncoagulated water, as illustrated in Figure 222. The chemicals most commonly used for the coagulation of water are compounds of alumina and iron, and of these potash alum, sulphate of alumina, and sulphate of iron are the most extensively employed.

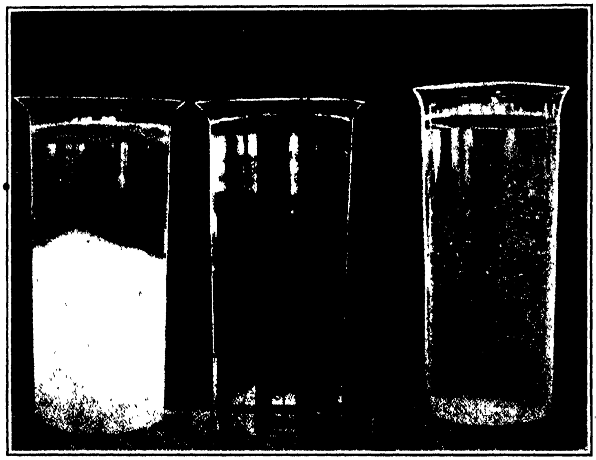


Fig 222

Originally no coagulants were used with slow sand filters but it has been found that, in the majority of cases, without some addition of foreign material a cloudy effluent with a high bacterial content is obtained at certain periods, especially following storms. The kind of coagulant to employ depends to a large extent upon the local conditions, although sulphate of alumina is almost always safe to use. In the Pittsburgh plant for example where acid waters, containing unprecipitated colloidal hydrates and silicates of iron, alumina, and manganese, complicated at times by the presence of organic coloring matter and paraffine-like bodies, must be treated, sulphate of alumina, lime, clay and bleaching powder are added either singly or in combination, according to the character of the river water at the particular time.

At many slow sand filter plants the final filtered product is sterilized with hypochlorites and most rapid sand filters which of course require the use of coagulants, sterilize the water.

The manufacture of alum is of great antiquity, and for many centuries this chemical has been used for coagulating water, as an aid to speedy clarification. The manufacture of aluminum sulphate from bauxite and lime clay is of more recent origin and the sulphate of iron used in water coagulation is, for the most part, a by-product of iron and steel industries, and developed by them in the last few years.

The choice between different coagulating chemicals is partly based on their efficiency as coagulants, and this, for example, refers directly to the percentage of available alumina or iron which they contain if sulphates of aluminum and iron are being considered. The amount of coagulating chemical depends upon the character of water to be treated, especially the turbidity or color of such water. Very turbid or very highly colored waters frequently require several grains of coagulating chemical per gallon. This quantity may be equal to seventeen parts per million by weight and as one grain per gallon of sulphate of alumina requires for its decomposition about seven parts per million of alkalinity this means that for the seventeen parts per million of alumina one hundred and nineteen parts per million of the carbonates and bicarbonates of lime and magnesia, naturally present in the untreated water, are converted into the sulphates of lime and magnesia.

When potash alum or sulphate of alumina is applied to water the chemical is rapidly and completely decomposed by the alkaline compound naturally present in the water. Ordinarily this alkalinity is due to carbonates and bicarbonates of lime and magnesia and the sulphuric acid portion of the coagulating chemical displaces the weak carbonic acid of the alkaline compounds above mentioned. As a result soluble sulphates of lime and magnesia are formed and equivalent amounts of carbonic acid and alumina are liberated. The latter unites with the water and forms the white, insoluble and gelatinous precipitate, known as aluminum hydrate, and which has the property of massing together various impurities as mentioned above. The former or the carbonic acid is usually decomposed by the alkalinity naturally present in the surface water but if the natural alkalinity is low the deficiency is made up by applying soda ash or lime to the water. When sulphate of iron is used as a coagulant it is ordinarily necessary to add lime, as copperas (iron sulphate) decomposes somewhat similarily to alum but the resulting bicarbonate of iron is partly soluble and more or less granular. By adding lime, bicarbonate of iron is changed to the gelatinous ferrous hydrate, which in turn is oxidized into ferric hydrate which is insoluble and gelatinous and serves well in the massing together of impurities. Care must be taken in the addition of the lime as too little causes incomplete precipitation of the iron and some appears in the effluent while too much lime results in lime incrustations.

Where waters in their raw state are normally clear and colorless practically no preparatory treatment is required before filtration and waters which are comparatively clear, but highly stained by decaying vegetation, and which require treatment for the removal of bacterial life, may be purified by slow sand filtration. Such treatment, however, will remove only a relatively small part of the color dissolved in the water, and if it is desired to remove all of this color a coagulating chemical must be used. To use coagulants effectively and economically in connection with sand filters the period of preliminary coagulation and sedimentation should usually be at least 18 hours and preferably 24 hours.

Muddy waters are largely caused by mineral matter in suspension which mineral matter varies greatly in size so that although a large part may settle out on standing some particles are less than 1/100,000 of an inch in diameter and consequently remain in suspension. It is necessary with such waters to have basins large enough to permit of adequate subsidence of the coagulated matters before the water reaches the filter, otherwise the surface of the sand becomes clogged too quickly, requiring cleaning at prohibitively frequent intervals. The practice of clarifying muddy water to be used for drinking purposes, by coagulation with compounds of alumina followed by sedimentation, probably originated in China thousands of years ago but up to fifteen years ago it was not looked upon with great favor because of the idea that it produced an ill effect upon the health of communities using water so treated. At the present time, however, the use of coagulants is recognized not only as necessary for treatment of certain classes of waters, but as permissible for use with perfect safety.

The use of coagulants is of prime importance for boiler feed water especially where hard water is encountered. The filters employing zeolites for this purpose have been discussed in Chapter IV and in addition to these the American Water Softener Company uses a synthetic zeolite under the trade name of Decalso, which, although brought into contact with the water in a different manner, gives the same chemical reaction.

The zeolites used are generally sodium aluminum silicates and the chemical reaction which takes place in the softening of the water is the exchange of the sodium in the zeolite for the calcium and magnesium in the water. As the total hardness of water consists of temporary and permanent hardness, the former calcium and magnesium bicarbonates, which on boiling partially split up and precipitate as insoluble carbonates, and the latter consists of sulphates and chlorides of calcium and magnesium, the passing of water containing either or both of these forms of hardness through sodium aluminum silicate, entirely removes the hardness by the exchange of the calcium and magnesium for the sodium. The zeolites are regenerated, as stated in Chapter IV, by ordinary salt. In the first case the sodium chlorides, sulphates and carbonates are soluble and do not precipitate in the boiler while in the regeneration the calcium and magnesium chloride are soluble and easily washed out of the filter. When it is desired to remove iron and manganese from the water manganese zeolite which has been treated with permanganate is used. The grains of the zeolite after treatment with the permanganate are coated with highly unstable oxides of manganese which have a powerful oxidizing power. When water containing oxidizable substances passes through this zeolite, oxidation is affected by the oxygen given off. The zeolites are regenerated, or re-oxidized in this case, by the introduction of solutions of potassium or calcium permanganate.

Besides zeolites the lime and soda ash process and tri-sodium phosphate are extensively used for eliminating the hardness from water. The soda also neutralizes acidity and removes from water its corrosive tendencies. Tri-sodium phosphate precipitates both carbonates and sulphates of lime and magnesia and as the chemical action is very rapid sedimentation tanks can often be dispensed with, if the water does not contain an appreciable amount of suspended matter.

As stated in the first chapter (Principles of Filtration) one of the greatest aids to filtration is heat and this may be said to hold true for practically all solutions. Whenever it is possible to raise the temperature of a slurry prior to filtering this should be done, if it is economically possible, as an increase in the filtering rate of from 50 to 100 per cent will thus be obtained with a corresponding increase in the washing efficiency and the ease of discharging.

The use of free filtering foreign material which is inert in the slurry to be filtered and which has approximately the same specific gravity has rendered possible the filtering of a great number of materials which otherwise could not be handled and has greatly increased the efficiency in filtering numerous other materials. In the mining field, Merrilite, a powdered zinc dust used for precipitation purposes in cyanide solutions, Filter-Cel (a diatomaceous earth), and paper pulp used in sugar clarification to prevent the clogging of the filter medium, are examples of foreign materials used as filter-aids.

Where gelatinous or albuminous substances are to be filtered the use of filter-aids is especially valuable. Without the filter-aid the first filtrate runs cloudy and the gelatinous particles soon form a thin and almost impervious layer over the filter cloth. A coating of this kind is practically impossible to remove, as the interstices of the filtering medium are filled with the gelatinous material in such a manner that they can not be cleaned out. The use of a preliminary coating of such a material as Filter-Cel or paper pulp prevents the gelatinous material from getting into the pores of the filter medium and at the same time insures a clear filtrate from the start. The amount of filter-aid to use depends upon the colloidal-like nature of the solids in the slurry and of course upon the value of the product. Ordinarily only a small percentage is necessary, in fact the amount is sometimes so small, as in sugar work, that the deposit can hardly be seen upon the filter medium yet the filtrate is clear, the rate of flow is increased and the cloths are easily cleaned. It may be said that any material may be filtered if sufficient filter-aid is used unless the liquid is extremely viscous, but of course this is often not economically feasible. The use of several per cent of filter-aid causes a heavy cake to be readily built up, which is especially desirable where continuous or leaf filters are employed, as the capacity of the filter is increased not only in cake discharged but also in the rate of flow.

Lime is used as a coagulant and filter-aid in water clarification, settling ore slimes, defecating sugar juices, precipitating colloidal pigments, aluminum compounds, etc. It is not always the best material to employ for these purposes however as high organic impurities tend to make it ineffective and large quantities are necessary to get good results. Filter-Cel or material of this class and paper pulp (Figure 223) are two of the best practical filter-aids used. They are light, yet porous and free filtering and usually inert to the slurry to be filtered.

Filter-Cel is largely used in filtering varnish, sugar, vegetable oil, lubricating oils, cotton seed oil, cocoanut, etc., where the quantity needed is comparatively small (Figure 224) and the extra expense is more than counter-balanced by the increased filtration efficiency. Filter-Cel like other materials, however, can

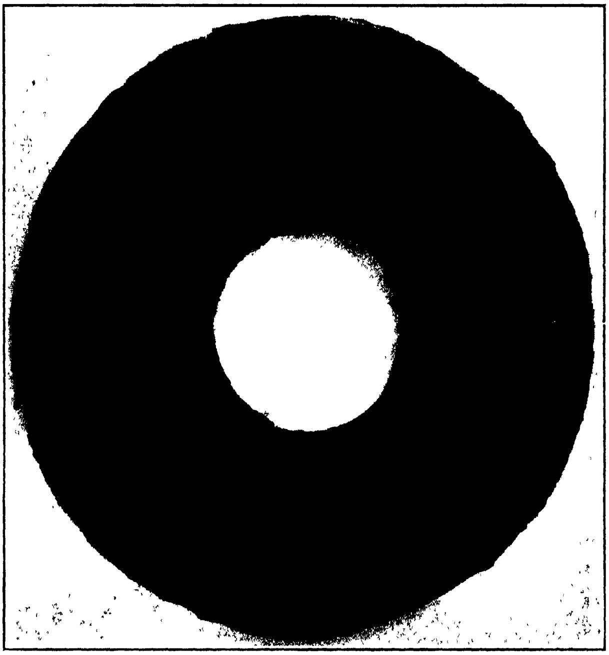


Fig. 223
Paper Pulp Cake
Vallez Rotary Filter

only be used where its presence is not detrimental to the cake. There are a few cases as in paraffin where the Filter-Cel can be recovered but this is very often not the case. Paper pulp, especially in the sugar industries, is recovered by washing and used many times thus making it a cheap filter-aid.

Fuller's earth, charcoal, asbestos, sawdust, paper pulp, magnesia, talc, lime, gypsum, and numerous other materials are used as filter-aids and they give excellent results if properly employed but of course some are much better than others in specific cases. Where flocculent or colloidal materials are encountered a fine enough filtering medium to give a clear filtrate will cause a very low rate of flow and any increase in pressure simply forces the solids into the mesh of the filtering medium, thereby plugging them so that all filtration is stopped. If however the filtering medium had been pre-coated with a filter-aid or a filter-aid had been mixed with the material to be filtered, or both methods had been followed, there would have been no clogging of the medium or impervious layer formed. It is usually desirable to both pre-coat the leaves and mix the filter-aid with the slurry where gelatinous or colloidal materials are encountered. In this way not only is the filter medium protected to start with, but during filtration, the gelatinous particles are separated and upon being deposited on the filtering medium, they form more or less porous layers. These layers do not shut off the flow of liquid through the medium and are therefore relatively easy to dry and discharge.

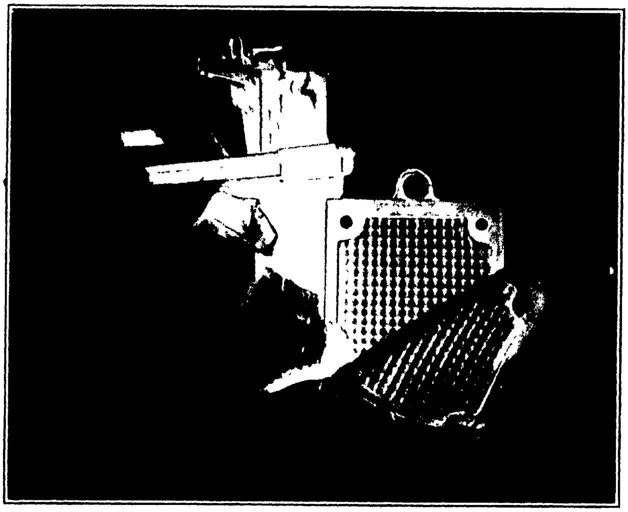


Fig. 224
Filter-Cel Matrix

Many decolorizing carbons and earths as Super-Filtchar, Darco, Carbrox, Norit, Kelpchar, Filtrol, etc., are manufactured to act both as decolorizers and as filter-aids for oils, fats, lactic acid, sugar, alcoholic solutions and materials of this general class.

In conclusion it might be said that settling and decantation of the supernatant liquor where practical are of great aid to filtration for two special reasons. In the first place the removal of a large bulk of the liquid by decantation eliminates the necessity of drawing that liquor through the filter cake, and in the second place the old law which states that when particles approach each other by a distance less than five times their diameters they have a tendency to clump, seems usually to hold good. The use of settling is naturally dependent upon the material to be handled, the space available, etc., but it should not be passed over without due consideration particularly in the handling of flocculent materials.

CHAPTER XIV

FILTER MEDIA

The filtering media in use depend largely upon the material being filtered and the type of apparatus employed for such filtration. Although nature and the arts have produced a very large number of porous mediums those employed to any extent in practice are comparatively few. Filter mediums generally consist of paper pulp, sand or gravel, vegetable fiber, precipitates, fabrics of cotton, wool, hemp, hair, metal, asbestos, etc., porous bricks or stone, charcoal (animal or vegetable) bagasse, sawdust, vegetable horse hair, infusorial earth, wood, straw, etc. They may be classed in a variety of ways but the best criterion seems to be, whether the particles forming the medium are rigid or flexible. Rigid particles may form a medium in two ways. They may be either simply in contact, or they may be agglomerated or fused together. The former structure is that of gravel, sand and similar material and the latter is that of various types of porous plates or cylinders. The filter composed of particles simply in contact has the advantage of cheapness and of being easy to keep clean by rearranging the particles, assisted if necessary by other means. By suitably selecting the size of particles the section of passages may be regulated through extremely wide limits. In water filtration or clarification for example, beds of gravel and sand are used which range in thickness from a few inches to several feet, therefore, any particles which pass through the top layer are assumed to be caught in the interior of the filter bed so that a clear filtrate is obtained. Often the first few minutes of filtration after cleaning will show a cloudy effluent but this soon clears up as the impurities catch in the interior of the filter bed and thus reduce its porosity. It is obvious of course where high pressures are used finer filtering media must be employed in order to get good results.

As a general rule fine, clean sand makes the best filter bed for straight water clarification, while charcoal, Fuller's earth, etc., give better results in removing oil from water or in oil filtration. The depth and size of sand to use has become practically standardized both in rapid and slow sand filters. Wherever extraordinary impurities are encountered in slow sand filtration preliminary chemical treatment is resorted to, while in rapid sand filtration chemical treatment is almost always made use of, so that no change need be made in the filtering bed.

Such materials as zeolites described under water filters, and filter-aids, described in Chapter XIV, do not properly come under the discussion of filter media and therefore will not be taken up here.

The drawbacks of a rigid medium simply in contact are; first, that it can only be used conveniently in a horizontal position and second, it does not permit the easy removal of thick deposits of cake without similiar disturbances of the filtering medium. A medium consisting of rigid particles in rigid connection, on the other hand, may be gauged as regards its porosity with great nicety, may be used in any position, and permits of the easy removal of the cake. It has the further advantage that the size of the passages is absolutely fixed and the medium does not allow solid matter at any time to pass through if it has been properly selected. This quality chiefly distinguishes it from the filtering materials we have next to consider, *viz.*, those consisting of flexible particles.

One of the most used of mediums consisting of rigid particles rigidly connected, is Filtros described in Chapter XII. Other materials are porous stone, unglazed porcelain, Alundum, etc., employed either in the laboratory or for the handling of free filtering corrosive materials.

Porous bricks are sometimes used for the filtering of sulphide of arsenic from sulphuric acid. The bricks are usually 9 inches x 6 inches x 24 inches and are built up on draining tiles at the bottom of a tank, used as a gravity filter, although pressure may be employed.

Fabrics or flexible mediums, for filtering purposes are made of many different materials and of various thicknesses, texture tensile strength, etc., to meet the demands of industry. They have the advantage of being easy to manipulate, wash and renew, and can be used in any position. They are employed chiefly to suspend or retain sediment for which purpose they have an open texture, the exact size depending upon the material to be filtered.

It is obvious that a medium consisting of flexible particles may be built in two ways, irregular contact, or the particles may be arranged so that the medium assumes a definite structure as with textile or paper.

Paper pulp is sometimes used in filter presses for solutions that contain very fine, suspended, precipitates. The paper is made into a pulp with water and put into a form press where it is molded into a cake having the shape of the filter press frame. These cakes are dried and placed in the filter press where they serve to retain the finely divided solids and when clogged they can be taken out repulped, washed and remolded. The liquid is thus filtered through about two inches of closely packed filtering medium which requires less power to drive the filtrate through than that required by woven filter cloths, furthermore the fine precipitates are often of a gelatinous nature which would clog a medium such as filter cloth, but do not affect the paper pulp medium.

The fibers in a woven material preserve their relative positions through friction but cannot be said to be otherwise tied to each other. The sizes of the passages, therefore, in a flexible medium are not permanently constant. Furthermore the passages are not, as in a rigid medium, all of the same kind or order of arrangement. A woven material presents the interstices between the crossing threads of the warp and woof, between the individual strands in either, and between the elementary fibers forming each strand. The chief advantage of textile medium is its great tensile strength which comes into play owing to the peculiar method of support necessitated by its flexibility. In consequence of the latter the filtering medium has to be supported over a large number of points, such supports taking the form of corrugations, truncated pyramids, perforated plates, etc. Between the closely packed supports the cloth is simply in tension, whereas a solid medium similarly supported would be exposed to shearing strains or with supports further apart to bending strains, neither of which the usual porous mediums are well adapted to withstand, unless especially made of quite some thickness. The filter cloth on the other hand is of a thickness so small that the agglomeration of thirty or forty pairs of cloths is negligible when compared with the necessary dimensions of the apparatus. The lower limits of the size of the pores of the cloths also seem to be fairly high as for instance cloths which are in daily use, and which retain yeast cells, still permit lactic or butyric acid ferments to pass through easily.

As cotton cloth is probably the most important of the flexible fabric filtering mediums it might be well to take it up, rather at length. The rate of flow through cotton cloth is relatively low even with such light duck as unbleached muslin, when compared with sand filters and, therefore, it is customarily employed to handle slurries in which there is predominance of solids.

Cotton cloth for filtering is usually manufactured in three styles, plain weave of the ordinary over one and under one warp and woof, twill weave of the over two and under two with the next filling splitting the warp strands, design, and the chain weave, where one filling goes over two and under two, the next reversing this, the third a true twill sequence and with the next repeating the cycle. Of course in each weave there is considerable modification from the above, depending upon the weight of the yarn and the number of strands per inch. Cotton duck filtering cloth is sold, however, either by number or weight; *i.e.*, No. 42 is about the same as 16 ounce, twill and chain weaves are designated by the number of warp and filling members per inch, as No. 1842 where there are eighteen warp strands per inch and forty-two fillings.

In the use of heavy or thick cloth care must be taken to prevent the solids from becoming imbedded in the interior of the cloth so that although clean on the surface it is not impervious or nearly so, to the flow of liquid. This cutting down of the rate of flow often occurs in sugar filtration where strength is required in construction to prevent the bursting of the bags because of the weight of the liquor held within them. In the use of filter presses heavy cloths are sometimes employed so that they might form a gasket between the plates and frames and still not have to be replaced too often. Investigation has proved that the rapid clogging and difficulty in cleaning encountered with heavy cloths makes them a poor investment and they have been largely replaced by special weaves and redesigns of apparatus.

Unbleached muslin is a very efficient medium because it is so thin that ordinary precipitates do not become imbedded in the interstices of the cloth and the cloth can be readily cleaned. It is rather fragile, however, and must be handled with care. The use of double layers of cloth is seldom good policy except in dust collectors, for unless the two layers are closely united together a pin hole or slight tear in the outer cloth will allow the accumulation of sediment between the two cloths, which sediment cannot be removed and soon makes the renewal of the filtering medium necessary. If it is only desired that strength be given the filter medium or that abrasion be prevented a coarse mesh burlap or netting will give excellent results.

This burlap or netting need not be fastened to the filtering medium although care must be taken that wrinkles do not occur. A backing of this kind is almost always used on rotary filters and to some extent in leaf filters and presses. Cocoa matting was originally used in the Butters filter as a backing and support because of the very porous gathering space for solutions and the support which it gave the filtering medium. It was soon abandoned, however, because of its rapid clogging and cost of renewals.

The support given a filter medium mentioned at the beginning of the discussion of flexible mediums is also of importance, especially in leaf or rotary filters, as care must be taken to prevent collapsing or stretching and at the same time drainage must be maintained. For this last as large an area as convenient should be allowed for the passage of the liquor yet without lost space, always sufficient being used to prevent any back pressure.

The relative permeability of different weights of canvas is a difficult matter to determine experimentally. It is a function of the weave of the cloth and the character of the supporting surface. In general, the lighter the weight of the cloth the more permeable it is.

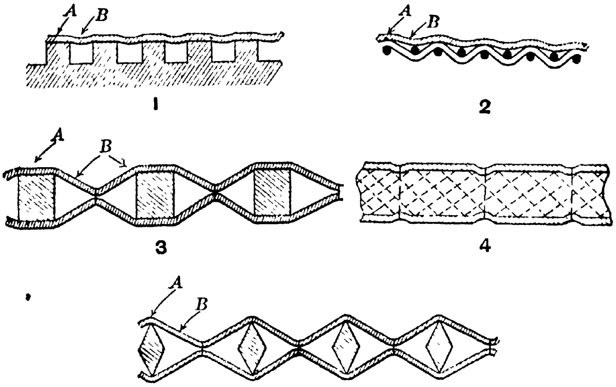


Fig. 225
Methods of Supporting Filter Cloth

Figure 225 illustrates several methods of supporting the filtering-cloth. In method 1, the fibers of the cloth are distended and the cloth made more open at "B," while at "A" the fibers are flattened and pressed against one another, with the result of reducing the permeability of the cloth over the ridges. The relative proportion of ridge to groove determines the decrease in permeability due to the support. No. 2 shows the wire netting support, and with this the rounded wires reduce the permeability to a less extent than the flat wooden ridges. In No. 3 the narrow wooden strips have less effect than the close ridges of No. 1, while between the strips the cloth is stretched and is more open. With No. 4 the permeability of the cloth is not generally effected, for the fibers may press into the soft cocoa matting. In No. 5 the diamond-shaped strips give the maximum proportion of distended canvas, and leave the fibers free from any flattening due to the pressure.

Figure 226, shows the effect upon the filtering-rate of slime for three filters. Curve "L" is for No. 12 duck on a grooved wooden support similar to No. 1, Figure 9; 41 per cent of the cloth was supported and 59 per cent unsupported. Curve "S" is for No. 12 duck supported on diamond-shaped strips; 21 per cent of the cloth was supported, 78 per cent unsupported. The dotted curve is the average curve for the test-filter. A No. 10 duck was used and the same proportion of support given the cloth as for curve "L." The heavier-weight duck on the grooved support gives a higher filtering-rate than the light weight on either the grooved or the more open support. The open support gives a higher filtering rate for the thinner slime cakes and lower rates for the thicker cakes. This anomalous result is explained by the fact that the more permeable the filter the more active becomes the filtering-surface for a given pressure and the more compactly the cake is built up. The general conclusion is that the permeability of the filter cloth is a matter of greater importance with thin cake suction filters than with the thick cake filters.

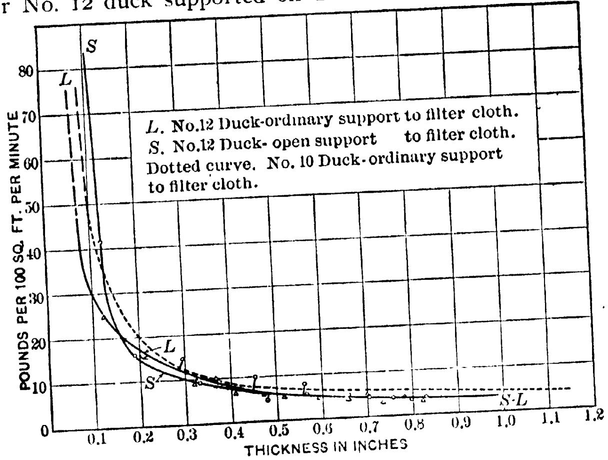


Fig. 226

Filtering-Rate of Slime for Three Types of Filters

Often a cloudy filtrate is obtained at first which filtrate can be re-run later on if the cloudy run is only of short duration. A procedure of this kind enables more open cloth than usual to be used and is made use of to a large extent in pressure filters.

The first cloudy filtrate in case of new cloth may be overcome as the cloth shrinks or swells. The amount of the shrinking and swelling being due to the tension under which the cloth is woven, the density of the threads, the number of intersections, etc. Duck or chain weave shrinks more than twill, but the latter will stretch more under the strain of filtering and discharging of the cake. This feature, therefore, makes it undesirable for leaf or rotary filters where the flow is reversed or compressed air sent in the reverse direction to filtration for the discharge of the filter cake. In cases where it is found necessary to use twill, for some special reason, the twill cloth must be tightly fastened and often needs taking up.

If caustic is not allowed to concentrate by drying in the mesh of the filter cloths cotton can be used with satisfaction up to concentrations of 10 per cent even in hot slurries. The life of the cloth in such cases being six to eight weeks. Cotton cloth, with care, can also be used for weak mineral acid slurries if handled cold and will have a life of from one to three months.

The nap or loose ends of cotton cloth is greatest in short staple stock and this nap often causes the cake to discharge with difficulty. It may be burned off without greatly weakening the strength of the cloth and it is generally a better procedure than mercerizing for this reason.

In general, however, where caustic or mineral acid slurries are to be handlled a woven metal cloth, such as monel metal wire cloth, is the best medium to employ. Monel metal can be used on practically any strength of caustic solution and on mineral and mixed acids usually up to 20 per cent concentration. Monel metal is twelve times as strong as cotton of the same weave and, of course, is not subject to shrinkage, swelling, or stretching. If it were woven .0027-inch mesh with wire of .0023 inch in diameter it would weigh only one ounce to the square foot but would be too weak to be practicable, so it is not woven finer than approximately 350-mesh. The monel metal has wedged-shaped openings which permit the filtrate to pass through rapidly and in time cause the cake to form against a protective and solid backing. This is illustrated by taking a drop of water and attempting to pass it through a round or square hole. It will be observed that this can not be done as easily or with as little pressure as when a rectangular opening is used, as an orifice for the water, the reason being that the drop is elongated and passes through by gravity to which is added capillary attraction when a volume is sent through. The main objection to metal woven cloth is that finely divided solids will pass through the pores of the cloth which only ranges up to about 350-mesh (mesh as fine as 500 is usually found only in pure nickel cloth). If it is not desired to save the solids and it is economically possible a filter-aid may be used to insure a clear filtrate. In the case of monel also, care must be taken to prevent electrolytic action being set up which will destroy the cloth.

Wool of various weaves is used a great deal for acid solutions up to about 10 per cent concentration, depending upon the acid and the temperature. A mixture of asbestos and monel metal also is used, the monel metal being employed to give strength to the asbestos which is too soft to be a good filter medium, otherwise, although it is often so used. For special work other metals may be woven with the asbestos and a relatively strong fine mesh cloth obtained.

No standardization of filtering medium can be made in general industrial filtration such as is possible in water filtering, and the selection of the proper filter medium to employ is often a difficult problem. This is especially true of slurries containing finely divided materials, where a medium with large enough pores to give an economical rate of flow, yet small enough to give a clear filtrate, must be selected. Each class of problems and usually each problem, therefore, must be treated separately and a few experiments must be carried on in order to determine accurately the best filtering medium to employ under the peculiarities and requirements of the proposition.

CHAPTER XV

OPERATING DATA

A great deal might be said concerning the fine points of operation in a discussion of any one filter and an equally lengthy discussion might be given about the various types and styles, but in a volume such as this all that can be profitably taken up is the available charts and tables on the several classes of apparatus as outlined in the table of contents.

There are many types concerning which there are no reliable data because of the great variations of results or because of the recent invention of the apparatus; others are not of sufficient complication to require special operating information, or have been taken up in such a manner as not to need further discussion, so they are not mentioned in this chapter.

Water Filters.—As has been stated before, the greatest advance in standardization and in the general methods of control and operation of filtering apparatus has been made in water filtration the growth of which is illustrated in Figure 227. For slow sand filters, Table IV gives the average rate of flow, while the flow of rapid sand filters is shown in Table V. The numerous automatic alarms employed and convenient operating tables used make water filters very easy to control and if care is taken to provide for sudden turbidity due to storms, etc., little trouble is ever encountered, although the sedimentation tanks and the coagulant feeders, where used, need systematic inspection. If proper sized equipment is originally installed, with adequate sedimentation capacity and provision for coagulation, with the selection of good graded sand, efficient sand valves, back washing and cleaning apparatus, the duty of the operator is simply one of general supervision and routine. Therefore no lengthy discussion of the operation or care of these types of filters need here be made.

Figure 228 illustrates very clearly the heat losses due to scale while Table VII completely refutes the argument that coagulation tends to increase the scale forming properties of water so treated.

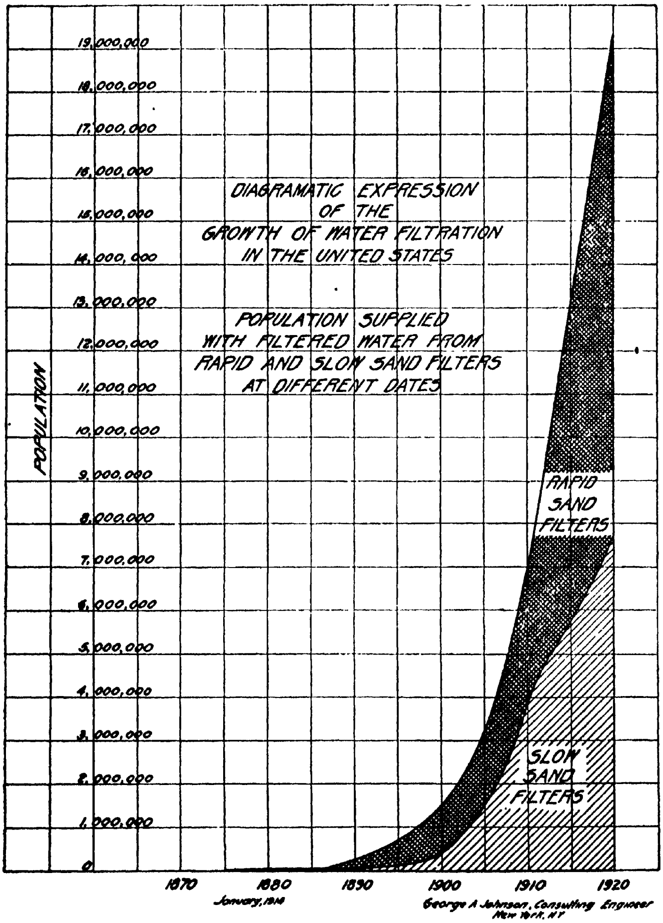
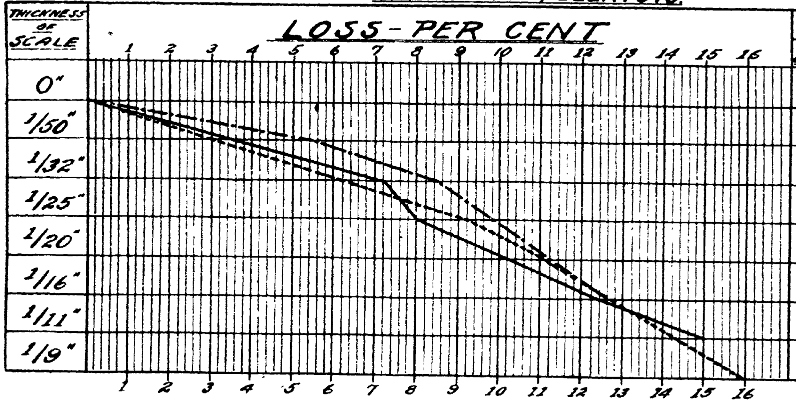

DIAGRAMATIC EXPRESSION
OF THE
GROWTH OF WATER FILTRATION
IN THE UNITED STATES
POPULATION SUPPLIED
WITH FILTERED WATER FROM
RAPID AND SLOW SAND FILTERS
AT DIFFERENT DATES
POPULATION
19,000,000
18,000,000
17,000,000
16,000,000
15,000,000
14,000,000
13,000,000
12,000,000
11,000,000
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
RAPID SAND FILTERS
SLOW SAND FILTERS
1870
1880
1890
1900
1910
1920
January, 1914
George A Johnson, Consulting Engineer
New York, N.Y.

Fig. 227

HEAT LOSS DUE TO SCALE

BASED ON PROF. SCHMIDT'S DETERMINATIONS AT THE UNIVERSITY OF ILLINOIS,
CHAMPAIGN, ILLINOIS.



THICKNESS OF SCALE	DOLLAR & CENT LOSS Per 1000 Tons of $3.00 Coal.		
	SOFT CARBONATE	HARD CARBONATE	HARD SULPHATE
0"			
1/50"	116.00	162.00	90.00
1/32"	216.00	255.00	186.00
1/25"	240.00	279.00	279.00
1/20"	309.00	333.00	333.00
1/16"	324.00	378.00	378.00
1/11"	450.00	429.00	429.00
1/9"		477.00	477.00

CHARACTER OF SCALE—
FULL LINE = SOFT CARBONATE.
DOT & DASH LINE - HARD CARBONATE. —·—·—
DOTS = HARD SULPHATE. - - - - - -

Fig. 228

TABLE IV.—SCHEDULE OF SIZES, CAPACITIES, AND WEIGHTS—GRAVITY WATER FILTERS

Capacities shown are the minimum rate for muddy and contaminated waters

Diameter	Height of filter tank	Inlet and outlet pipes	Waste pipes	Capacity in U. S. Gallons			Approximate shipping weights—Lbs.		
				Minute	Hour	24 Hours	Tank	Parts	Filter beds
8′	7′	4″	5″	100	6,000	144,000	2,800	3,300	19,000
10′	7′	5″	6″	157	9,420	226,080	3.700	4.400	29,500
13′	7′	6″	8″	265	15,900	381,600	5,200	6,050	50,000
15′	7′	6″	8″	353	21,180	508,320	6,200	7,050	66,800
17′	7′	8″	10″	454	27.240	653,760	7.000	10,050	86,000
8′	7′	4″	5″	100	6,000	144,000	2,800	3,300	19,000
10′	7′	5″	6″	157	9.420	226,080	3,700	4,400	29,500
13′	7′	6″	8″	265	15,900	381,600	5.200	6,050	50,000
15′	7′	6″	8″	353	21,180	508,320	6,200	7,050	66,800
17′	7′	8″	10″	454	27,240	653,760	7,000	10,050	86,000
6′	16′	3″	6″	57	3,420	82,080	8,300	2,000	12,000
8′	16′	4″	6″	100	6,000	144,000	11,700	3,000	20,000
10′	16′	4″	8″	157	9,420	226,080	14,700	4,000	32,000
12′	16′	6″	8″	226	13,560	325,440	18,500	7,000	46,000
14′	16′	6″	8″	308	18,480	443,520	22,600	8,000	62,000
15′	16′	6″	8″	353	21,180	508,320	25,500	10,000	71,000
17′	16′	8″	8″	454	27,240	653.760	29,700	17,000	91,000
24′	16′	10″	10″	905	54.300	1,303.200	32.000	18,000	160,000
6′	7′	3″	6″	57	3.420	82,080	5,000	1,500	12,000
8′	7′	4″	6″	100	6,000	144,000	5,800	2,500	20,000
10′	7′	4″	8″	157	9,420	226,080	7,000	3,500	32,000
12′	7′	6″	8″	226	13.560	325,440	9,000	6,000	46,000
14′	7′	6″	8″	308	18,480	443.520	11,000	7,000	62,000
15′	7′	6″	8″	353	21,180	508,320	12,000	9,000	71,000
17′	7′	8″	10″	454	27,240	653,760	15,000	15,000	91,000
24′	7′	10″	10″	905	54.300	1,303.200	20,000	16.500	160,000
8′ 8″	8′ 5″	8″	6″	118	7,080	169,920	3,600	8,430	12,500
10′ 6″	8′ 5″	8″	6″	173	10,380	249,120	4,400	9,040	18,000
12′ 6″	9′ 11″	8″	6″	245	14,700	352,800	5.500	10,210	26,000
13′	9′ 11″	8″	6″	265	15,900	381.600	6,400	10,250	28,000

Capacities given are based upon a rate of two gallons per square foot of filtering area per minute.

TABLE V.—WATER PRESSURE FILTERS

Height	Size of connections	Rate of filtration		Shipping weight				
		Gal. per min	Gal. per hour	Case	Pipe and fittings	Valves	Sand and gravel	Approximate total weight
4′	1″	5- 8	300- 480	...	...	...	....	900
4′	1″	7- 10	420- 600	...	...	...	....	1300
4½′	1¼″	10- 15	600- 900	...	...	...	....	1600
5′	1½″	15- 25	900- 1500	850	300	200	1800	3150
6′	2″	20- 35	1200- 2100	1000	350	200	3000	4550
6′	2″	30- 50	1800- 3000	1300	400	200	3800	5700
6½′	2½″	40- 60	2400- 3600	1700	450	225	5700	8075
6½′	2½″	50- 80	3000- 4800	1800	475	225	6400	8900
7′	3″	60- 100	3600- 6000	2400	500	320	9600	12820
7′	3″	70- 120	4200- 7200	2650	600	320	10800	14370
7½′	4″	85- 150	5100- 9000	3600	650	450	11200	15900
8′	4″	100- 165	6000- 9900	4000	650	450	16400	21500
8′	4″	115- 190	6900-11500	4500	650	450	18100	23700
8′	5″	130- 220	7800-13200	5800	700	840	19300	26640
9′	5″	150- 250	9000-15000	6500	800	840	23100	31240
9′	5″	210- 350	12600-21000	7600	1000	950	30000	39550
9′	6″	300- 525	18000-31500	9500	1500	1200	40100	42300
9′	6″	425- 700	25500-42600	12000	2000	1400	55000	70400
9′	8″	635-1050	38000-63000	16400	3300	2000	77800	99500

Table VII shows practically all there is to the proposition that coagulation seriously affects the water for steam raising purposes. The only detrimental change which takes place is the formation, in the water, of some six or eight parts per million of incrustants for every grain per gallon of coagulant used. Such small increase could not be measured detrimentally by the steam user, and the undesirable features surrounding their presence in the filtered water are more than offset by the advantages inherent in a boiler water which is free from silt and clay.

While the fact that a water is hard always announces itself in unmistakable fashion to the user, the actual degree of hardness can only be determined by chemical analysis.

There are many reasons why water should be softened. In the first place, water is the substance which enters more largely into human affairs than any other. Population is greatest in the regions having abundant supplies of water, and where these abundant supplies are pure, clear and, by comparison with other natural waters, soft, industries will flourish more vigorously, and the inhabitants will live more comfortably and more happily.

TABLE VI.—CHEMICAL AND BACTERIOLOGICAL RESULTS, EAST JERSEY WATER CO., LITTLE FALLS, N. J.

Averages—(For Fiscal Years Beginning September 1st)

Year and month	Average period of service	Filtered water million gals a day		Per cent of wash water	Sulphate of alumina		Parts per million						Bacteria per cubic centimeter	
		Total	Net		Pounds per day	Grains per gallon	Alkalinity		Turb		Color			
							River	Fil	River	Fil	River	Fil.	River	Fil
1902–1903	9.55	12.8	12.4	3.5	2,330	1.28	28	19	11	1	35	6	3,500	70
1903–1904	10.55	17.2	16.7	2.8	3,060	1.26	29	21	18	0	34	6	2,600	55
1904–1905	10.89	23.0	22.4	2.6	4,150	1.28	33	24	12	0	29	5	1,500	50
1905–1906	10.52	22.1	21.4	3.2	4,720	1.49	27	16	8	0	32	4	2,500	110
1906–1907	9.29	24.5	23.6	3.8	4,340	1.24	30	22	9	0	25	3	2,000	65
1907–1908	10.23	24.7	23.8	3.6	4,940	1.41	24	14	9	0	31	3	1,300	35
1908–1909	10.38	24.2	23.4	3.5	4,930	1.44	32	22	9	0	28	3	2,900	48
1909–1910	10.41	26.8	26.0	3.7	7,740	2.05	32	21	10	0	40	5	5,300	100
1910–1911	11.36	28.4	27.3	3.9	4,530	1.12	31	24	11	0	45	8	4,500	16
1911–1912	12.73	30.8	29.9	2.8	5,450	1.25	26	18	11	0	48	8	3,100	3
September, 1912 . . .	10.80	30.8	29.9	3.1	6,450	1.47	41	30	7	0	41	8	750	2
October	10.63	30.7	29.8	3.1	8,790	1.93	35	23	10	0	56	7	1,100	4
November.	11.00	29.4	28.5	3.0	13,320	3.16	22	7	10	0	61	14	2,000	4
December.	15.14	30.3	29.6	2.3	7,790	1.86	23	12	8	0	40	11	1,800	3
January, 1913	15.29	28.9	28.3	2.2	4,370	1.06	14	7	8	0	39	7	1,300	2
February	17.72	31.8	31.2	1.9	6,120	1.36	23	14	8	0	31	9	1,000	1
March	13.45	29.1	28.4	2.5	3,470	0.84	15	10	12	0	43	8	1,500	2
April	13.19	28.1	27.4	2.5	4,410	1.10	18	11	7	0	40	8	800	1
May	11.15	28.7	27.8	3.0	6,070	1.48	27	16	8	0	44	7	1,200	0
June	10.67	30.7	29.8	3.1	7,060	1.61	36	24	8	0	49	10	600	1
Average	11.90	26.7	25.9	3.0	6,702	1.48	27	18	10	0	40	7	2,063	29

TABLE VII—HARDNESS OF RIVER WATERS AT VARIOUS PLACES BEFORE AND AFTER COAGULATION AND FILTRATION.

City	Average for year	Kind of filters	Amount of coagulant used Grains per gallon	Parts per million				Increase of incrustants in filtrated water due to use of coagulants
				Total Hardness		Incrustants		
				River	Filtered	River	Filtered	
Springfield, Mass...	1912	Slow sand	(d) 0.24	11	11	2	4	2
Little Falls, N. J....	1903	Rapid sand	(d) 1.38	31	30	7	14	7
Louisville, Ky......	1912	Rapid sand	(d) 1.73	95	91	29	38	9
Cincinnati, Ohio....	1910	Rapid sand	(a) 0.84 (b) 1.79	76	89	32	41	9
New Orleans, La....	1912	Rapid sand	(a) 4.41 (b) 0.33	111	60	21	25	4
Columbus, Ohio....	1910	Rapid sand	(a) 7.5 (c) 4.3 (d) 1.57	270	85	111	35	Softened

(a) Lime; (b) Iron; (c) Soda ash; (d) Sulphate of alumina.

There is another class of water-treating material which is used largely to remove scale already formed and to some extent to prevent the formation of new scale, graphite and kerosene being most often used for these purposes. Their action seems to be entirely mechanical and opinions as to the desirability of their use vary from enthusiastic commendation to absolute condemnation, though their use seems generally approved by practical men. Neither should be used, however, in boilers in which there is already a heavy deposit of scale, as the loosening of this and its accumulation in the bottom of the boiler is apt to lead to blistered and bagged boiler metal. Both graphite and kerosene should be used very cautiously. Kerosene, if used in excessive quantity is apt to distil over and attack gaskets.

Proper air agitation aids in ridding the water of its excess carbon dioxide and helps to collect the impurities and keep them out of solution. With unsoftened water the calcium and magnesium salts in the water deposit upon the air nozzles and clog them; with softened water this trouble does not occur.

Water which produces a dirty, discolored cake with a lot of white patches scattered through it and a large white central core on freezing, should be treated. The kind of treatment to employ and the results to expect depend upon the nature and amount of the impurities present. It is the temporary hardness of the water or the bicarbonates of lime and magnesia which come out of solution when the water is frozen and leave dirty, grayish deposits. This happens because freezing sets free the carbon dioxide which holds these in solution and causes their precipitation. This effect becomes apparent when they are present in the water to the extent of only a few grains per gallon and becomes more troublesome in proportion to the increase of the amount present.

Water containing the bicarbonates of lime and magnesia can be treated to great advantage no matter how much is present. If there are less than 8 or 10 grains present, it is usually advisable to use a zeolite treatment. This will convert them to the less objectionable sodium salts which do not form dirty deposits in the ice. If the amounts present are greater than this, a lime treatment should be given which will remove them from the water except for 3 or 4 grains and give a much improved water for ice making. If desired this water may then be passed through zeolite to change this calcium and magnesium carbonate remaining to the less objectionable sodium salt. The lime treatment will also remove iron and suspended matter from the water.

If the water contains permanent hardness as the sulphates, chlorides or nitrates of calcium or magnesium their conversion to the corresponding sodium salt can be obtained either through the use of soda in a lime soda plant or by the use of a zeolite, as there is no way of entirely removing them from the water except by distillation. The magnesium salts are the most undesirable in ice making as they are apt to discolor the cake giving it a grayish or greenish tinge. Both the calcium and magnesium salts may deposit to some extent throughout the ice as well as concentrate in the core making it white and retarding freezing, so the change to the sodium salt is a decided improvement.

Sodium salts, however, in large amounts are objectionable because they concentrate in the core, making white ice and hold back freezing. Drawing the core and replacing it with fresh water is of benefit when these sodium salts are high.

In considering the advisability of treating a water and the best method to pursue the above mentioned facts must be taken into consideration. There are salts causing temporary hardness, permanent hardness and some sodium salts in the water. Part of the temporary hardness can be taken out of the water by the use of lime, leaving around five grains of calcium carbonate. But the best that can be done with the permanent hardness is to change it to an equal amount of sodium salt. The sodium salts will remain as they were. After treatment the sodium salts present which have been formed from the salts causing permanent hardness plus the sodium salts naturally in the water determine its suitability for ice making. The amount that will be left can be approximated by adding together the grains per gallon of permanent hardness and the grains per gallon sodium salts. The permanent hardness includes all the salts of calcium and magnesium aside from their carbonates, that is the sulphates, chlorides and nitrates.

If the treated water contains less than 12 grains per gallon total dissolved solids, very good ice can be made using low pressure air agitation. Softened water containing from 12 to 20 grains total dissolved solids will make very good ice but high pressure air agitation must be used. As the total solids present increase in amount past 20 grains the quality of the ice deteriorates and the difficulty of making it increases. Treatment will always improve it but cannot always make it satisfactory. If the water contains a large amount of temporary hardness a lime treatment should be given it to remove it from the water.

WATER FROM COLUMBUS, OHIO
Zeolite Treated Water

	Grains per gal		Grains per gal.
Calcium carbonate	3.60	Sodium sulphate	8.04
Magnesium carbonate	0.08	Sodium chloride	0.90
Magnesium sulphate	3.00	Total dissolved solids	16.21
Iron and aluminum oxide	0.11	Total hardness	6.20
Silica	0.48	Alkalinity	3.70

For this water a straight zeolite treatment should be employed. A lime soda softener would not decrease further the amount of carbonates present and the conversion of those already present together with the permanent hardness to the sodium salt can be made most simply and conveniently by the use of a zeolite.

WATER FROM SCHLESWIG, IOWA
Lime-Zeolite Example 1

	Grains per gal		Grains per gal.
Calcium carbonate	15.90	Sodium chloride	1.73
Calcium sulphate	1.85	Sodium nitrate	5.10
Magnesium sulphate	5.22	Total dissolved solids	31.57
Iron and aluminum oxide	0.05	Total hardness	21.80
Silica	0.44	Alkalinity	15.90
Magnesium chloride	1.28		

In this water, dropping out the calcium carbonate by lime treatment will bring down the total solids present under the 20-grain mark and the remaining hardness may be changed to the sodium salt by passing the lime treated water through a zeolite.

In Table VIII the capacity of a filter using deoleizer is shown where the purified waste steam is to be used for the manufacture of ice.

TABLE VIII.

No	Dimensions		Max pipe size In	Cap per hour			B H P	Tons ice per day
	Diam. In.	Height In.		Gallons	Pounds	Cu ft		
1	15	33½	1½	125	1,050	17	35	10
2	20¼	38	2	250	2,100	34	75	20
3	27¼	44½	2½	500	4,200	68	150	40
4	36	52¾	3	1,000	8,400	136	300	80
5	43¼	60¼	3½	1,500	12,600	204	450	120

Centrifuges—The operation of centrifugal machines is one which requires a good deal of intelligence despite the fact that very often ignorant labor is employed for this work. Care must be taken in charging to see that neither an overload nor an underload is sent to the basket and equal care must be taken in the application of wash water to get an efficient wash with a minimum of water. In machines which are not self-dumping wooden cleaners should be used and particular attention should be paid to the perforated plates or replacements will be very high. Tables IX and X illustrate average results obtained from centrifuges.

TABLE IX.

Baskets				Turbines	Revolutions per minute	Peripheral velocity Feet per minute	Centrifugal force Pounds per pound	Weight (Approximate)	
Dimensions		Capacity		Nominal H P				Net	Gross shipping
Width	Depth	Total	Wall						
42″	18½″	14 cf	5.6 cf	5 h. p.	850	9346	431	4175	4650
48″	18½″	18.5 cf	7.12 cf	5 h. p.	700	8796	334	4650	5200
60″	18¾″	25.5 cf	11.85 cf	10 h. p.	500	7854	213	7250	7650
72″	22½″	38 cf	16.75 cf	15 h. p	450	8482	207	9300	10150

TABLE X.—CAPACITIES OF CENTRIFUGALS

Type of centrifugal	Self-balancing iron case						Self-balancing wood case		Self-balancing annular discharge				Open top		Solid curb			Acid wringer	Sus-pended
Diameter of basket	12″	26″	32″	40″	48″	60″	60″	72″	26″	32″	40″	48″	42″	48″	12″	16″	20″	36″	40″
Cu. ft. { Total	.294	3.22	6.25	12.7	19.3	32.8	32.8	47.8	2.58	4.6	9.6	14.5	10.9	14.5	.42	.76	1.53	12.4	14.9
Cu. ft. { Under top ring	.158	1.57	3.52	6.4	10.0	16.4	16.4	23.2	1.25	2.58	4.8	7.5	6.7	8.5	.17	.23	.59	6.2	7.3
Gallons { Total	2.2	24	46.6	95	144	245	245	357	19.2	34.2	72	109	81.4	114	3.15	5.7	11.5	93	112
Gallons { Under top ring	1.2	11.7	26.3	50.5	7.48	122	122	173	9.4	19.3	36	56	50.8	63.5	1.27	1.72	4.4	46	55
Bushels { Total	.236	2.59	5.02	10.2	15.5	26.4	26.4	37.6	2.07	3.68	7.6	11.6	8.8	11.9	.34	.61	1.2	10	12
Bushels { Under top ring	.127	1.26	2.83	5.42	8.0	13.2	13.2	18.7	1.01	2.08	3.9	6.0	5.4	6.8	.137	.185	.47	5	5.9
Maximum load in pounds allowed	...	180	300	600	900	1200	1200	1400	150	250	500	750	650	750	25	50	75	400	600
Centrifugal force at normal speed	800	365	365	410	335	215	215	210	365	365	410	335	385	335	335	320	310	365	560

TABLE XI.

Size	Capacity in cu ft. per hour	H P. req		R P. M counter shaft	R P M basket	Size driving pulley	Net weight	Weight boxed for export	Cu. ft. cargo space	Height
		A C	D C.							
10″	200	20	15	1000	3000	14″ x 4″	1100	1300	35	3′ - 0′
24″	800	35	25	700	2100	20″ x 6″	7000	7700	155	6′ - 11½′
36″	2500	45	35	660	1600	24″ x 6″	12000	13750	300	7′ - 9′
48″	4000	55	45	515	1100	30″ x 10″	17000	18300	610	8′ - 10½′

Table XI shows the capacities, etc., of various sizes of continuous centrifuges.

TABLE XII.—DATA ON TEXTILE EXTRACTORS

Size of basket	30″	36″	42″	48″	54″	60″
Revolutions per minute	1150	950	800	700	600	500
Velocity in feet per minute	9040	8954	8796	8796	8483	7854
Centrifugal force of one pound at periphery, pounds	563	461	382	334	276	213
Size of engines	4″x4″	4½″x6″	4½″x6″			
Size of engines	3″x3″	3″x3″	4″x4″	4½″x6″	4½″x6″	6″x8″
Size of pulleys	12½″x5″	12½″x5″	16″x8½″	16″x8½″	22″x8¾″	22″x8¾″
Speed of pulleys	575	475	400	350	300	250
Width of belt	4″	4″	7″	7″	7″	7″
Approximate shipping weight	2000	2500	3800	4800	6000	7400
Horse-power of motors	3	3	5	7½	7½	10

SIZE OF STEAM PIPE CONNECTIONS TO ENGINES

Size of engine	3″x3″	4″x4″	4½″x6″	6″x8″		
Inlet	½″	1″	1¼″	1½″		
Exhaust	1″	1½″	2″	2″		

Air Filters.—There is not a great deal of air filter data available. First, because air filters are more of a newly developed economy than a vital step in manufacturing and second, because the apparatus is practically automatic.

The temperature variations tables give an idea of the ordinary range of factory temperature and the advantages of uniformity of temperature can easily be figured out.

Hydraulic Presses.—The subject of hydraulic presses has been discussed rather at length so that the table given of an olive oil press will serve to typify this class of filters and additional details need not be given.

TABLE XIII.—Specifications for an Olive Oil Hydraulic Press

Number	Pressure capacity	Size of cheese	Stock space	Run of ram
18 S. L.	500 tons	18 inches x 36 inches	60 inches	30 inches
20 S. L.	550 tons	24 inches x 48 inches	58 inches	40 inches

Oil Filters.—The most common theory employed in the construction of oil filters is that of separation by differences of specific gravity. Therefore the principle facts to bear in mind in the operation of these machines are the prevention of emulsions (the oleite filter excepted) the proper period of retention to permit the impurities to drop out and the oil and water to separate naturally.

TABLE XIV.

Units	Filtering capacity per day of 24 hours Gallons	Pure oil chamber Gallons	Waste oil chamber Gallons	Water chamber Gallons	Length Inches	Width Inches	Height Inches
1	250 to 400	90	20	40	42	28	36
2	500 to 800	180	40	80	84	28	36
3	750 to 1200	270	60	120	126	28	36
4	1000 to 1600	360	80	160	168	28	36
5	1250 to 2000	450	100	200	210	28	36
6	1500 to 2400	540	120	240	252	28	36

Table XIV shows what results may be anticipated in an average oil filter.

Filter Presses.—A considerable amount of semi-intelligent labor is necessary in filter press work and as filter presses are one of the most important types of filters one or two commonly recognized features of operation should be emphasized. In setting up a press special care should be taken to see that the cloths are straight and unwrinkled when the press is closed, even at the expense of considerable time. Wrinkled cloths cause leaky presses, may result in cloudy filtrate, and always result in early replacements. The proper design of pressure pump should be looked into and the pump used operated so that a uniform pressure is built up. A third important point is the systematic inspection of the strainer to insure the prevention of objectionable material getting into the press.

TABLE XV.—TABLE OF SIZES, CAPACITIES, ETC., FOR SQUARE FILTER PRESSES

Size of press Inches	Number of chambers	Filtering area in square feet		Thickness of cake inches	Cubic capacity 1-inch cake		Working pressure per square inch		Inside dimensions of frames	
		Cast-iron press	Wooden press		Cast-iron press	Wooden press	Cast-iron press Pounds	Wooden press Pounds	Cast-iron press Inches	Wooden press Inches
12	6	10	5.81	1 to 3	.42	24	150	100	11 x 11	7¾ x 9
	12	20	11.62		.84	48				
	18	30	17.43		1.26	73				
18	12	47	30	1 to 3	1.95	1.24	150	100	16¾ x 16¾	12¾ x 14
	18	70	45		2.92	1.86				
	24	94	60		3.89	2.48				
	30	117	75		4.87	3.10				
24	24	169	115	1 to 3	7.03	4.81	150	100	22½ x 22½	18¾ x 19
	30	211	144		8.79	6.02				
	36	253	173		10.55	7.22				
	42	295	202		12.30	8.43				
30	24	252	182	1 to 3	10.50	7.58	100	75	27½ x 27½	22¾ x 24
	30	315	227		13.12	9.48				
	36	378	273		15.74	11.38				
	48	504	364		20.98	15.17				
32	30	362	262	1 to 3	15.08	10.94	100	75	29½ x 29½	24¼ x 26
	36	434	315		18.10	13.13				
	48	579	420		24.13	17.51				
	54	652	. . .		27.15	.				
36	36	561	381	1 to 3	23.36	15.90	100	65	33½ x 33½	27¼ x 28
	42	654	445		27.26	18.55				
	48	748	508		31.15	21.18				
	54	841	. . .		35.04					
42	36	800	544	1 to 3	33.34	22.68	75	65	40 x 40	32¾ x 33¾
	42	933	635		38.88	26.46				
	48	1067	726		44.44	30.24				
	60	1334	. .		55.55	. .				
48	42	1102	. . .	1 to 3	45.90		75	. . .	45½ x 45½	. . .
	48	1258	.		52.42					
	54	1416	. . .		58.98					
	60	1573	. . .		65.54	.				

TABLE XV. (Continued)—TABLE OF SIZES, CAPACITIES, ETC., FOR RECESSED CIRCULAR FILTER PRESSES

Size of press inches	Number of chambers	Nominal filtering area in square feet	Thickness of cake inches	Cubic capacity		Working pressure per square inch Pounds
				1-Inch cake	1¼-Inch cake	
12	6	8	1	27	. . .	150
	12	16		55		
	18	24		82		
	24	32		1 09		
18	12	37	1 or 1¼	1 31	1 64	150
	24	73		2 62	3 28	
	36	110		3 93	4 91	
27	18	128	1 or 1¼	4.80	6 00	150
	24	170		6 40	8 00	
	30	213		8 00	10.00	
	36	255		9 60	12 00	
	48	340		12 80	16 00	
36	36	461	1 or 1¼	16 92	21 15	100
	48	691		23 76	29 70	
	60	768		29.70	37.13	
	72	921		35.64	44.55	

Burt Revolving Filters.—In Table XVI, is shown a tabulated statement of tests conducted at El Oro with a Burt revolving filter to determine the washing efficiency and capacity of this machine. The ratio of solids to liquids in the pulp fed to the filter was 1 to 1.126, and the screen analysis as follows:

Mesh	Percentage
+100	2.6
+150	23.2
+200	8.4
—200	65.8

The amorphous matter or absolute slime in the feed was 38.4 per cent. The extraction during the pressing was gold $0.22, silver 1.1702 ounces. The pulp fed to the filter having been incompletely treated in the plant the water used in washing contained no value.

The diagram in Table XVII shows the washing efficiency of the machine. The average rate of removal of gold, silver and total value is shown, and the amount of cyanide during washing with the amount of barren solution required to affect the same in tons per day of dry ore.

Number of charges put through the filter	13
Average thickness of cake	4.3
Average dry metric ton per charge	5.24
Average pressure per square inch during cake building	38 lbs.
Average pressure per square inch during washing	48 lbs.

SCREEN ANALYSIS

Mesh	Percentage
+100	2.6
+150	23.2
+200	8.4
—200	65.8

The average percentage of colloidal matter in the feed to the filter was 38.4 per cent.

TABLE XVI

Time charging pulp—minutes	Time forming cake—minutes	Time adding wash water—minutes	Ratio wash water to dry ore	Duration of washing in minutes	Thickness of cake—inches	Time discharge and preparing for next cycle—minutes	Total time of cycle—minutes	Heads to press evaporated pulp			Heads to press re-washed pulp			Moisture in cake as formed	Moisture in sludge discharged to waste	Assay of tailings as discharged			Assay of tailings after re-washing			Un-washed value discharged		
								Au $	Ag oz	$	Au $	Ag oz	$			Au $	Ag oz.	$	Au $	Ag oz	$	Au $	Ag oz	$
								Per ton			Per ton			%	%									
3	22	5	0.9-1	20	3.5	3	53							20.6	—	0.78	0.69	1.22	0.72	0.84	1.14	0.06	0.05	0.08
3	25	5	0.83-1	32	3.75	3	68	3.14	3.30	4.79	0.88	1.90	1.83	21.4	—	0.74	0.86	1.17	0.70	0.84	1.12	0.04	0.02	0.05
3	36	5	0.83-1	20	3.75	3	67	3.14	3.30	4.79	0.88	1.90	1.83	22.6	—	0.75	0.88	1.19	0.66	0.82	1.07	0.09	0.06	0.12
4	20	8	1.09-1	33	4.5	2.5	67.5	3.14	3.30	4.79	0.88	1.90	1.83	21.8	26.5	0.72	0.80	1.12	0.76	0.80	1.10	0.02	—	0.02
4	22	5	0.68-1	24	4.5	2.8	57.8	3.14	3.30	4.79	0.88	1.90	1.83	22.0	25.4	0.72	0.77	1.10	0.72	0.75	1.09	—	0.02	0.01
4	28.5	5	0.68-1	24.5	4.5	3.0	65	3.14	3.30	4.79	0.88	1.90	1.83	—	—	0.75	0.84	1.17	0.65	0.88	1.05	0.10	0.04	0.12
4	21	6.66	0.909-1	30	4.5	2.7	64.36	3.14	3.30	4.79	0.88	1.90	1.83	19.5	26.0	0.62	0.65	0.94	0.56	0.64	0.90	0.04	0.01	0.04
4	22.5	6.66	0.909-1	37	4.5	3.0	78.16	3.14	3.30	4.79	0.88	1.90	1.83	19.9	26.4	0.62	0.64	0.94	0.58	0.63	0.89	0.04	0.01	0.05
4	25	6.33	1.14-1	50	4.5	3.0	90.33	3.14	3.30	4.79	0.88	1.90	1.83	—	24.6	0.74	0.67	1.07	0.74	0.65	1.06	—	0.02	0.01
4	24	6.33	1.14-1	52	4.5	3.0	91.33	3.14	3.30	4.79	0.88	1.90	1.83	20.5	—	0.65	0.57	0.93	0.65	0.58	0.94	—	—	—
4	22.5	10.0	1.36-1	66	4.5	2.8	110.30	3.14	3.30	4.79	0.88	1.90	1.83	21.2	25.3	0.62	0.65	0.94	0.62	0.65	0.94	—	—	—
4	34	10.0	1.36-1	64	4.5	3.0	115.00	3.14	3.30	4.79	0.88	1.90	1.83	22.0	25.6	0.60	0.64	0.92	0.62	0.64	0.94	—	—	—
4	20	13.4	1.81-1	90	4.5	3.0	130.3	3.14	3.30	4.79	0.88	1.90	1.83	20.5	—	0.72	0.82	1.13	0.72	0.82	1.13	—	—	—
Avge. 3.76	25.5	7.4	1.05-1	41.7	4.3	2.9	81.4	3.14	3.30	4.79	0.88	1.90	1.83	21.1	25.7	0.69	0.74	1.05	0.66	0.73	1.03	0.03	0.07	0.04

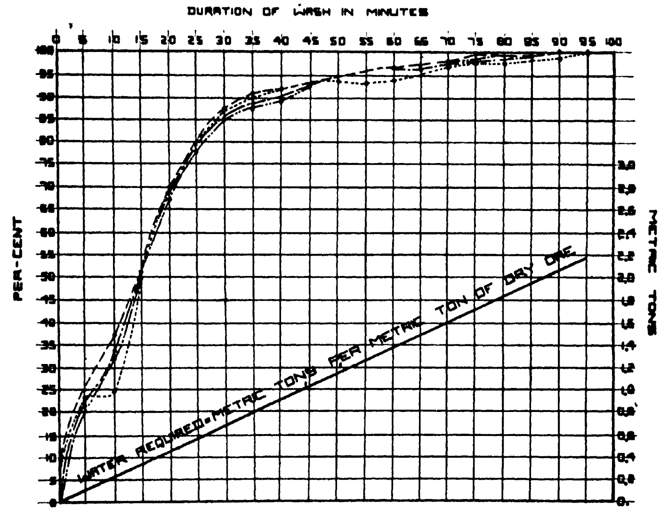


Fig. 229

Phillippe Filter.—As Phillippe Filters are operated and fed by gravity proper supervision of intake and outlet as well as careful removal and replacement of filter cloths are all the special instructions necessary for this type of apparatus.

TABLE XVII.

Size (Bags per filter)	Filtering surface per bag Sq in.	Total filtering surface Sq. ft.	DIMENSIONS			Shipping weight Lbs.	Cap. gal per hour	
			Length Inches	Width Inches	Height Feet		Juice	Syrup
14	1550	150	28	30	4′—0	1540	532	140
20	1550	214	40	30	4′—0	1760	760	200
32	1550	342	60	30	4′—0	1980	1216	320
40	1550	428	75	30	4′—0	2420	1520	400

Kelly Presses.—In operating the Kelly Filter Press instructions as to the opening and shutting of the press, manipulation of compressed air and wash water valves and the advised method of feeding must be strictly adhered to in order to get good from the machine.

Table XVIII gives the specifications of Kelly Filter Presses.

TABLE XVIII.

Type of press	30	150	250	450	850	900*	1300†
Floor space occupied	2x6 ft.	4x14 ft.	5x21 ft.	6x23 ft.	7x34 ft.	6x38 ft.	7x38 ft.
Size of press shell	20x36 inches	30x72 inches	40x108 inches	48x120 inches	60x168 inches	48x120† inches	60x108† inches
Capacity of shell { Cubic ft. gallons	5 40	32 240	75 560	120 900	275 2050	120† 900†	177† 1325†
Number of leaves	4-5	4-9	6-8	6-10	-12	6-10†	6-12†
Filter area, square feet	21-30	60-130	180-250	260-450	600-1050	520-900	600-1300
Weight of cake per cycle-cake 1½″-100 lbs. per cubic foot	200	1000	2000	5000	12000	12000	15000
Average cake tonnage 24 hours	—	5-10	20-40	50-100	150-250	200-500	200-800
Weight of press lbs.	750	3000	7000	11000	19000	21000	34000

* Twin units † One side only.

NOTE—Average capacities are approximate and vary with physical characteristics of the material to be filtered.

Sweetland Presses.—The Sweetland Filter Press operator like the Kelly operator must be carefully instructed and a set of rules for press operation should be posted near him for reference.

TABLE XIX.—General Data—Standard Sweetland Filters.

Filter numbers	Inside diam. Inches	Inside length Inches	Filter leaf spacing									Weight filter filled with water Lbs	Shipping weight lbs export
			2 inches			3 inches			4 inches				
			Number leaves	Filter area Sq. ft.	Nominal cake cap. Cu ft (½ in. thick)	Number leaves	Filter area Sq ft.	Nominal cake cap. cu ft. (1 in thick)	Number leaves	Filter area Sq. ft.	Nominal cake cap. cu. ft. (1½ in thick		
1	10	20½	9	9	.37	7	7	.58	5	5	62	550	650
2	16	36½	17	46	1.9	12	31	2.2	9	24	3.0	1850	2100
5	25	61	29	190	7 9	20	131	10.9	15	98	12.2	6050	5900
7	25	82	41	268	11.1	27	177	14.7	20	131	16.3	8550	8550
9	31	97	47	474	19.7	32	323	26.9	24	242	3.20	14400	14400
10	31	109	53	536	22.3	36	364	30.3	27	273	34.1	16450	15450
12	37	145	71	1030	42.9	48	695	57.9	36	522	62 2	27900	25900

Vallez Filters.—The Vallez Rotary Filter has rather a complicated set of valves to be handled, which valves must be thoroughly understood before operation of the press is attempted. Where paper pulp is used to build a matrix on the filter screen prior to filtration, the proper amount of pulp that must pass

TABLE XX.—General Data—Vallez Rotary Filter.

Filter number	1		2		3		4	
Inside diamete	16 inches		23 inches		38 inches		45 inches	
Inside length	36 inches		61 inches		120 inches		120 inches	
Width over all	22 inches		30 inches		48 inches		60 inches	
Length over all	66 inches		8 feet		16.5 feet		16 feet	
Weight of filter filled with water	1800 lbs.		4000 lbs.				25000 lbs.	
Shipping weight export	1200 lbs.		3800 lbs.				23000 lbs.	
Leaf spacing, inches	3½	2½	4	2½	4	2½	4	2½
Thickness of cake, inches	1	½	1¼	½	1¼	½	1¼	½
Number of leaves	10	14	15	22	30	45	30	45
Filtering area, sq. ft.	20	28	60	88	330	495	720	810
Cake capacity, cu. ft.	1.65	1.25	6.2	3.7	35	21	56.5	34

through the press to produce a desired thickness of deposit must be exactly worked out and details explained carefully to the operator.

Open Tank Filters.—If Open Tank Filters are used in sufficient size and number an electric hoist or crane is employed, which allows an even raising, lowering, and transferring of the basket of filter leaves. Otherwise care must be taken to prevent bumping and the consequent knocking off of portions of the filter cake. The rate of flow must be watched to see that the filter medium is submerged at all times although this last point can be taken care of automatically by overflow pipes and pumps, if so desired.

Figure 232 shows the variation of the filtering-rate with variable thickness of slime-cake both while building up and in clear water. The curves represent the averages of a number of tests in which temperature and pressure were practically the same for all. A No. 10 canvas was used. In carrying out the experiment the filter was immersed in the pulp for 5 or 10 minutes and a cake built up. This cake was then quickly removed, its thickness measured, and the filter immersed in clear water. After determining the filtering-rate, the filter was replaced in the pulp and an additional thickness built up. The filtering-rate during building up was determined by calculation from the amount of water passing while building to a given thickness. The difference between the two curves is comparatively slight and indicates that the filtering-rate during building up a cake is greater in the pulp than in clear water for thin cakes, while for the thicker cakes the reverse is true.

Figure 233 shows the effect of variation of pressure upon the filtering-rates of cakes of varying thickness. Three pressures were used—11.35, 17, and 21.5 inches of mercury. The general effect of increase of pressure is to increase the filtering-rate. This is more marked with the thin cakes, while with the thick cakes all three curves tend to run together. With thick cakes the effect of an increase of pressure is to increase the density of the cake and thus reduce its permeability. With higher pressures this effect is more marked, and indicates that a point would soon

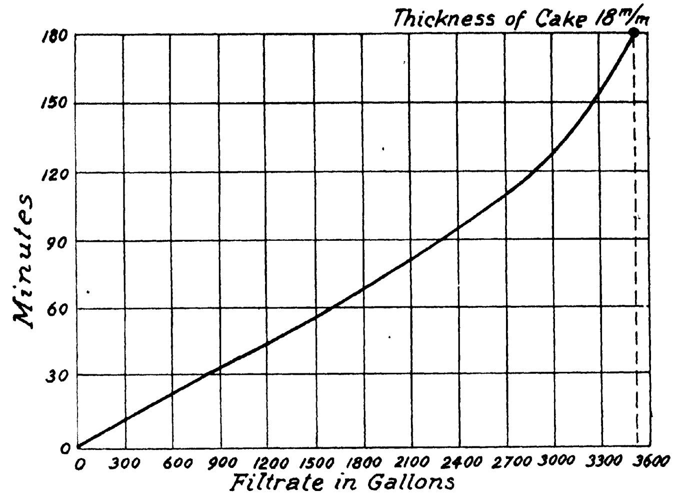


Fig. 230
Open Tank Filter

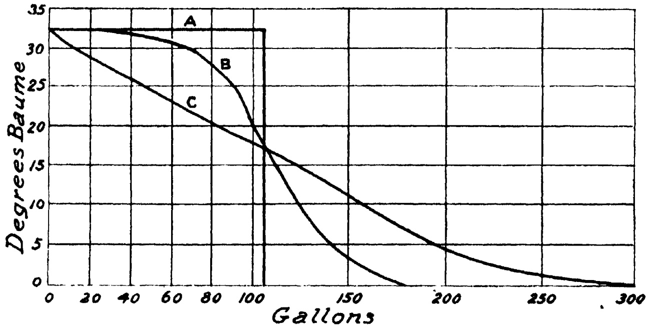


Fig. 231

A—Theoretical Washing
B—Washing in Open Tank Filter
C—Washing in Plate and Frame Filter

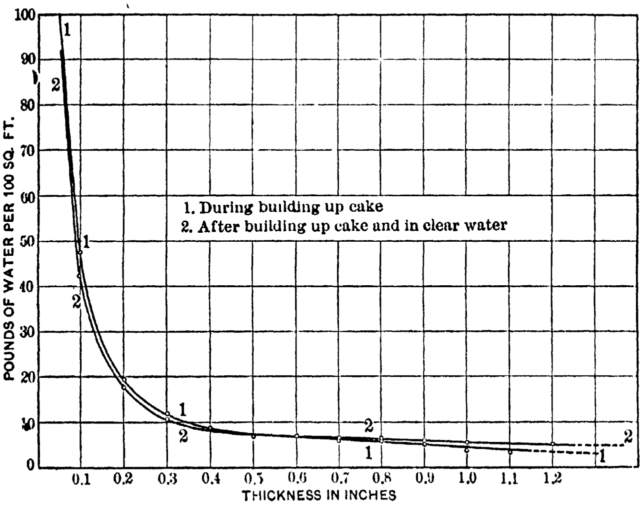


Fig. 232
Average Filtering-Rates for Slime-Cakes, No. 10 Canvas

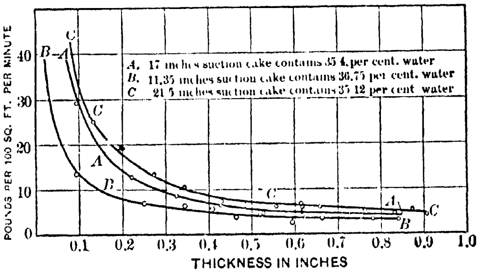


Fig. 233
Effect of Variation of Pressure upon Filtering-Rates, No 10 Canvas

be reached where the increased pressure would result in decreased filtering-rate. This is particularly true of slime containing a small proportion of sand, but much less so with slimes containing a large proportion of sand. Sweetland in his paper, "Pressure Filtration," shows for pressures up to 65 pounds per square inch

TABLE XXI.—DETAILS OF SLIME-PLANTS

	A	*B.*	*C.*	*D.*	*E*	*F.*	*G.*
Type of filter.	Open tank Filter	Open tank Filter	Open tank Filter	Open tank Filter	Merrill	Kelley	Filter
Number of units . . .	2	2	2	2	3	1	1
Number of leaves per unit.	60	95	168	72	64	10	100
Number of leaves, . .	120	190	336	100	192	. .	100
Area of leaf, sq. ft.,. .	100	91	100	92.6	41.4	. .	100
Total filtering-area,. .	12,000	17,290	33,600	9,262	7,980	360	10,000
Tons slime per 24 hrs.,	175	250	1,000	150	216	100	150
Tons slime per 100 sq. ft. per 24 hrs., . .	1.4	1.44	2.97	1.62	2.72	27.7	1.5
Slime-pulp consistency, water. slime,	3:1	3:1	1.5:1	2:1	2:1	1:1	2.1
Filter-support, ...	slats	slats	matting	slats	plate	wire netting	slats
Thickness of cake, in.,	1	0.75-1	1.25-1.75	1.25	1.75	1.5-2	1.5
Moisture in cake, p. c.,	38	35	35	33	.	12	29
Time forming, hr., . .	1	0.5	1-1.33	1	0.66	0.03	2
Time washing, hr., . .	1	1.0	1.41-1.66	1.25	0.41	0.20	2
Time transfers, hr., .	0.75	0.83	0.59-0.51	0.5	3.01	.	1.83
Total time-cycle, hrs.,	2.75	2.33	3-3.5	2.75	4.08	0.5-0.75	5.83
Filtering-rate per 100 sq. ft. per min., . .	11.6	26	8.3	6.83	30	. .	.
Filtering-rate per min. for wash, .	10	16.3	. .	.	. .	. .	. .
Tons of solution and wash per 24 hrs..	848	1,356	2,000	350-400	328 340	*a*75	434
Canvas used, oz., . .	12	12	12	12	18	12	10
Life of canvas, months, . . .	8	6	41 est.	18	12	0.5-1.5	. .
Frequency of acid-wash, days, ...	20	21	30	21	60	15	30
Approximate cost per ton slime	$0.18	$0.27	$0.075	$0.25	$0.238	$0.35	$0.119

*a*8-12 hrs

a progressive increase in the filtering-rate for slime-cakes varying from 0.5 to 1.75 inch. Unfortunately, neither a physical analysis of the slime nor the density of the slime-cakes formed is given in the paper. The slime-pulp was distinctly of a sandy nature and would be expected to give results of this kind, whereas a very clayey pulp would give results of an opposite character. Experiments with a slime of similar type, and with pressures ranging from 10 to 30 pounds per square inch, showed an increase in filtering-rate from 11 to 16 pounds of water per 100 square feet per minute for a cake of 0.25 inch in thickness; for a 0.5-inch cake an increase in pressure from 20 to 30 pounds decreased the filtering-rate from 10 to 7 pounds; for a 0.75-inch cake an increase in the filtering-pressure from 20 to 30 pounds make no difference in a filtering-rate of 6 pounds. R. Gilman Brown, in his paper, "Cyanide Practice with the Moore Filter," in discussing the treatment of a very clayey slime at Bodie, says: "Filter-pressing was tried and abandoned, because an eighth of an inch of pure slime would make the cloths impervious, even under 120 pounds pressure; and even if the slime were mixed with fine sand, the filtering was so slow that the sand settled out in the chambers, with the same result." The practical conclusion that may be drawn from a study of the effects of pressure in filtration is that, with material of a permeable nature such as a sandy slime, increased pressures over those obtainable by means of vacuum-pumps are advantageous, while with material in which only a moderate to a small amount of sand is present and the permeability low, the use of higher pressures offers no advantages over those obtainable by vacuum-pumps.

Rotary Filters.—Since rotary filters are continuous and automatic and revolve at a slow rate of speed they require practically no attention. When once the most efficient revolutions per minute,

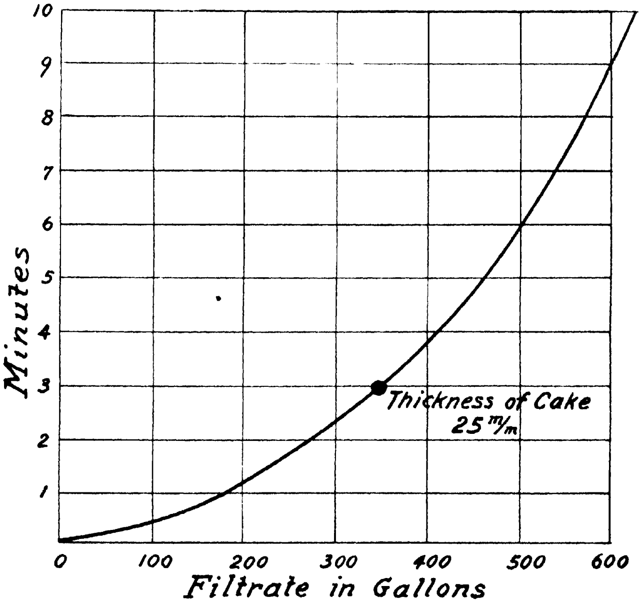


Fig. 234
Rotary Vacuum Filter

fed to the filter, and wash water is determined superficial supervision is all that is necessary.

Merrill Process.—The Merrill Process required a great deal of experimental work and still does with any new proposition. For operation, however, there are charts and tables which enable an intelligent operator to follow instructions easily.

MONTHLY AVERAGES OF RESULTS AND COSTS.

	Year	
	1906	1908
Minimum strength of solution precipitated	0.03%	0 015%
Average strength	0.03%	0.0242%
If below minimum strength, strengthened by addition of	Barren works solution of strength .07%	The lowest strength encountered .015%, is successfully precipitated
Tons precipitated	5,909	15,585
Dollars recovered, total	$1,513.00	$1,712.00
Dollars recovered, per ton solution	0.2560	0.3060
Average barren assay	0.0214	0.0178
Per cent precipitated	91.7%	94.4%
Pounds of precipitant used, pounds total	1,019	718
Per ton solution	0.1724	0.1285
Per dollar recovered	0.6735	0.4192
Value of precipitate per pound	$ 2.35	$ 4 03
Cost of precipitant	129.75	51 15
Cost of labor	97.50	19.75
Cost of miscellaneous supplies	16.03	6.03
All costs, total	243.28	76.93
All costs per ton solution	0.0412	0.0138
All costs per dollar recovered	0.1608	0.0449
Pounds cyanide in solution, wasted after precipitation	3,545	2,703
Value of same	$ 709.00	$ 540 60

SUMMARY

	Shavings	Dust	Saving by dust
All costs, labor and supplies	$ 243.28	$ 76.93	$166.35
Gold discharge in barren solution	126.45	99.41	27.04
Value of cyanide in wasted barren solution	709.00	540 60	168.40
TOTALS	$1,078 73	$716.94	$361.79

These solutions are unusually low both in strength of cyanide and assay value, but could a comparison be made of the two methods in the precipitation of the main working solutions of the plant, the results would be in favor of the zinc dust method.

Filter Cloths.—The following tables are some of the few curves available which deal with the rates of flow for varying filter cloths.

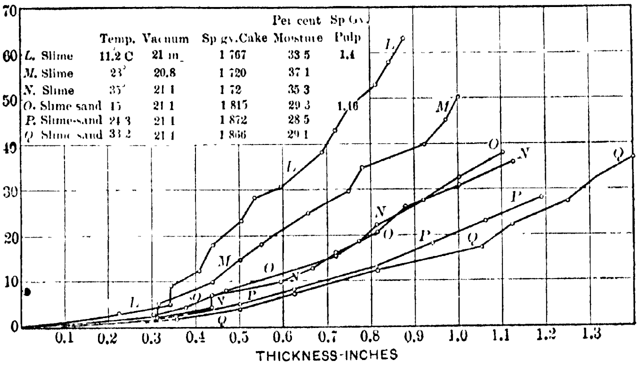


Fig 235
Rate of Building up Cakes, No 12 Duck

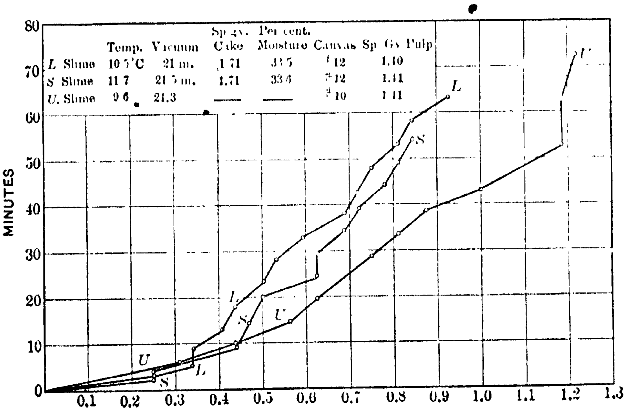


Fig. 236
Rate of Building up Slime-Cakes

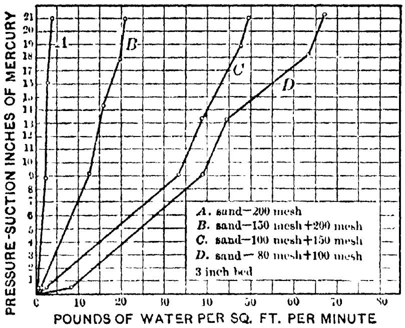


Fig. 237

Conclusion.—The foregoing is of course not comprehensive, but it will give an idea of the general operation result of most of the classes of filters described. For additional information on any special type it would be best to write to several manufacturers of such apparatus and request the desired information.

CHAPTER XVI

AUXILIARY EQUIPMENT

The successful operation of any filter is dependent, if it in itself is efficient and has intelligent control, upon the auxiliary equipment used with it. In water filters this consists mainly of coagulation tanks and apparatus, subsidence tanks, and in some cases centrifugal pumps. In other filters it consists principally of feeding devices and tanks, thickeners, filter press pumps, centrifugal pumps, rotary pumps, compressors, suction pumps, and intermittent receiving tanks. There are also strainers, filter cloth washers, and filter-aid recovery systems which it would be well to mention.

The size of coagulant tank to employ is as dependent upon the amount and kind of impurities to be removed as upon the capacities to be handled. In considering the removal of impurities and proper period of retention for sedimentation the very worst conditions which may occur must be taken into account, rather than the average.

Figures 238, 239 and 240, illustrate some of the methods of coagulant feeding which are in common use.

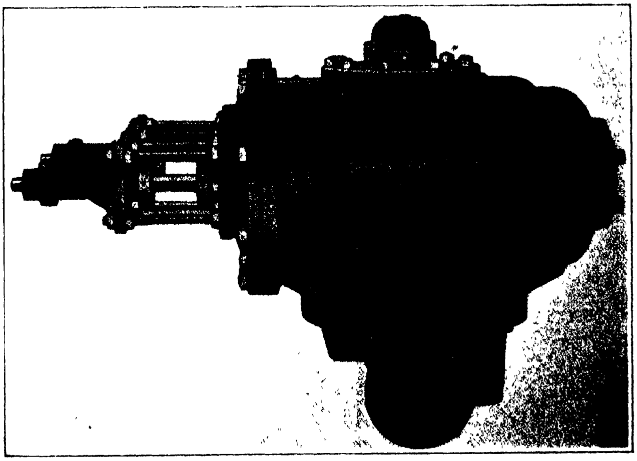


Fig. 238
Coagulation Feeder

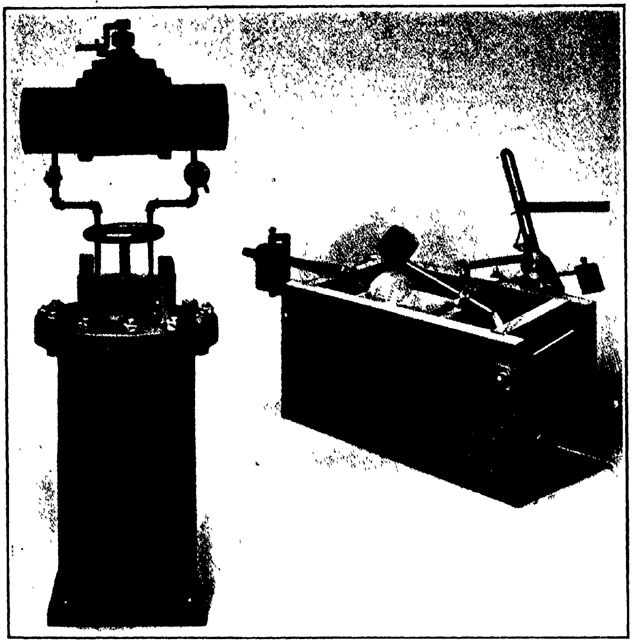


Fig 239 Fig 240

Coagulant Feeds

A typical reinforced-concrete coagulation and sedimentation basin with superimposed aerators has recently been put in operation by the Norristown (Penn.) Insurance & Water Co. to treat Schuylkill River water preliminary to filtration. Aëration is designed to remove tastes and odors from gas-plant wastes discharged into the river above the city. The filters are of the Jewell type and were installed twelve years ago.

Water is taken from a crib in the Schuylkill River through 1,800 feet of pipe to low-lift pumps. A coagulant is added to the river water in the force main. The latter discharges through a hydraulic control valve into an influent or receiving chamber

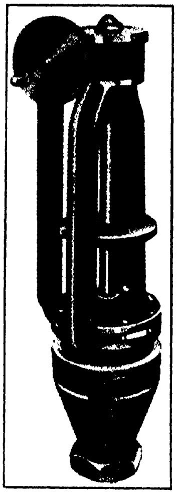


Fig. 241
Coagulator Feeder

(Figure 243) and thence through sluice gates to the two aerator units, each of which is arranged to discharge into its corresponding compartment of the sedimentation basin. Each unit consists of an inclined plane having an area of 230 square feet, covered with iron plates on which are cast projections arranged to break up the water and secure its intimate contact with air.

Each compartment of the sedimentation basin is 129 feet long and 63 feet wide. When filled to an average depth of 10 feet the whole basin has a storage capacity of 1,200,000 gallons. When supplying the filters at a rate of 5,250,000 gallons per 24 hours, the basins provide a 5½-hour period of coagulation and sedimentation and the average velocity of the water passing through the basin is about 0.8 foot per minute. Baffle walls cause the water to pass twice the length of the basin before discharging over the effluent weirs (Figure 243) on its way to the filters. The floors of the basin slope to clean-out valves, from which sediment pipes lead to the river. The sediment is pushed

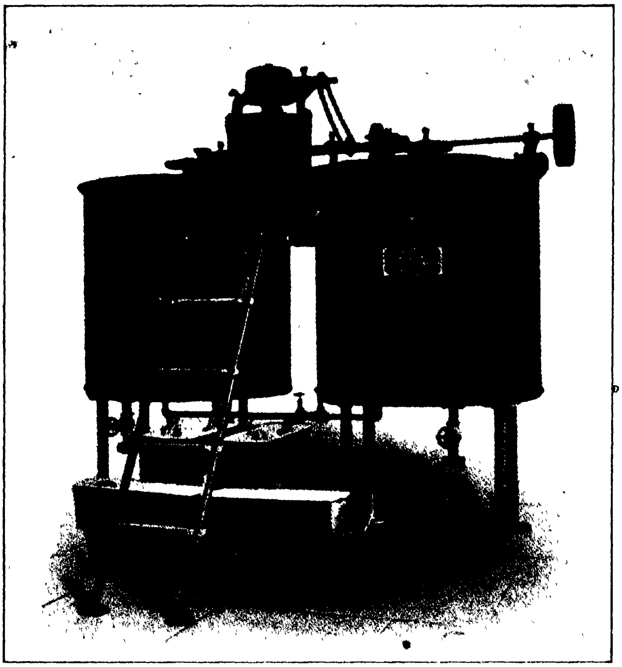


Fig. 242
Coagulation and Aerating System

to the pipes by hand and by flushing. An overflow pipe for each compartment is connected to the drainage system.

The hydraulic influent regulator already mentioned is a specially constructed valve operated by a float and pilot-valve mechanism arranged to maintain an approximately constant level of water in the basin.

Filters, other than water filters, are fed by means of elevated tanks, compressed air in conjunction with pressure tanks, special pumps, screw conveyors and special devices.

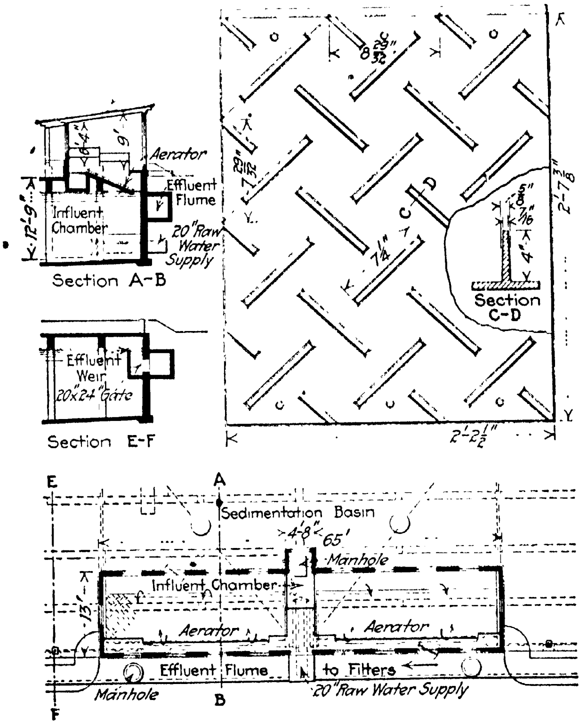


Fig. 243
Details of Norristown Water Aerator
Receiving Chamber and Aerator

Figure 244 shows the method of feeding a battery of centrifuges by means of a specially constructed conveyor and tank.

Dorr Thickener—A Thickener, such as the Dorr, is a mechanically operated gravity settler by means of which a thick underflow sludge and a clear overflow liquor are continuously produced from a feed made up of a mixture of finely divided solids and liquid.

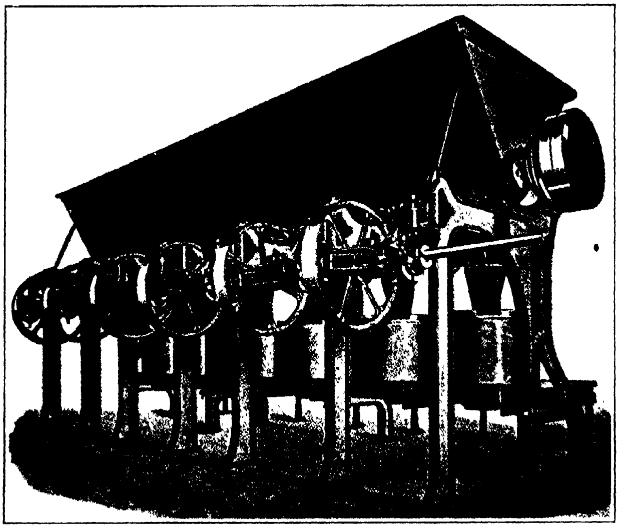


Fig 244
Centrifugal Feeding Device

It consists (Figure 245) of a tank or basin in which a slowly revolving mechanism sweeps settled solids to a discharge opening or openings by means of suitable plows. The feed enters continuously at the surface near the center, the clear liquor being continuously overflowed. A pump controls the discharge of the underflow which is often fed to a rotary vacuum filter.

Several different types of Thickeners have been developed to meet varying requirements and these types have been modified to handle particular products most efficiently.

Thickener mechanisms other than those of the peripheral drive design are carried and guided by supports resting on the tanks and can be raised by means of a lifting device, thus making it possible to start up after a shut-down or if for any other reason the arms become buried.

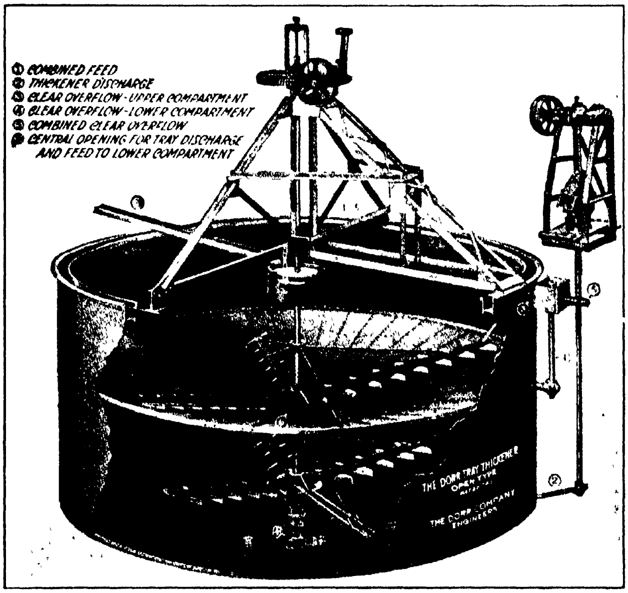

① COMBINED FEED
② THICKENER DISCHARGE
③ CLEAR OVERFLOW - UPPER COMPARTMENT
④ CLEAR OVERFLOW - LOWER COMPARTMENT
⑤ COMBINED CLEAR OVERFLOW
⑥ CENTRAL OPENING FOR TRAY DISCHARGE AND FEED TO LOWER COMPARTMENT
①
⑤
②
THE DORR TRAY THICKENER
OPEN TYPE
THE DORR COMPANY
ENGINEERS

Fig. 245
Dorr Thickener

The Dorr Thickeners are provided with an overload alarm to indicate the resistance offered to the mechanism, an alarm bell being rung when the load becomes excessive.

The flow of thin pulp should be delivered to a partially submerged feed well at the centre of the thickener, in which a float is set to prevent the formation of currents which might cause disturbances of the pulp in the tank.

Where the feed is under pressure it is generally advisable to discharge it into a small tank or barrel placed above the thickener, allowing the overflow to gravitate to the feed well.

Though thickeners were originally designed to handle nothing but the finest slime, to-day comparatively coarse sandy material can be successfully treated under certain conditions. Really coarse materials, however, or those of a stringy nature are likely to cause trouble in the discharge and should not be permitted to enter the thickener. Normally a stationary screen set in the feed launder will take care of this situation, but if any considerable quantity of material has to be screened out, such as leaves from ditch water, or fibrous and gelatinous substances from trade waste and sewage, the installation of a self-cleaning screen is advocated.

The degree of clarity is practically determined by the settling area provided, which point should be carefully considered when laying out any thickener installation.

Usually an overflow is considered satisfactory when it appears to contain no solids, except on close examination. In many industrial operations such as the clarification of water from blast furnace gas scrubbers, ditch waters and the treatment of various trade wastes and sewages, no economy results from complete clarification.

The control of the underflow of a thickener both in regard to density and volume is of the utmost importance.

The regulation of thickener underflow was first done by means of a nozzle and also by the use of air lifts.

In the former case when a thick product was discharged it was found that a slight increase in density greatly increased the friction so that the amount discharged was materially reduced, with a result that the thickener tended to choke down.

Though the use of air lifts appeared attractive they did not

To obtain absolutely satisfactory results it is essential that the underflow be controlled by positive displacement.

The Dorrco Pump (Figure 246) which has been specially devised for this purpose removes a given volume of sludge with each stroke. Should the sludge become denser the pump removes a greater amount of the solids so that the tendency is to bring the dilution back to normal.

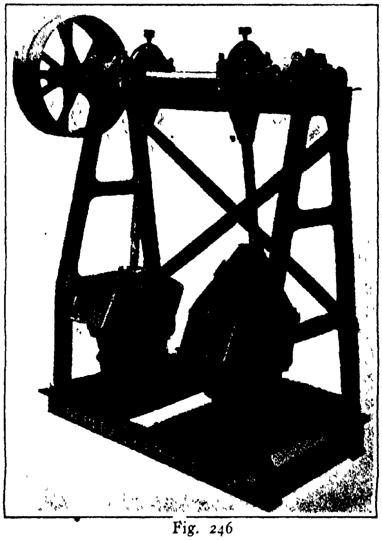


Fig. 246
Dorrco Pump

Where a heavy sandy product has to be handled or one containing some coarse granular material, the pump cannot always be advantageously used. In such cases a spigot discharge is advocated, thus obviating any building-up in the underflow pipe. Where relatively light solids have to be handled, as in sewage and trade waste operations, an upward discharge well is used from which the sludge is pumped.

The normal speed of rotation of a Dorr Thickener mechanism is approximately 10 feet per minute at the outer end of the long This speed may be increased or decreased according to the size of the thickener and the material handled. Generally speaking, with quick settling sandy material the speed should be increased, and with light material decreased. Care should be exercised that the thickener rakes are not operated too slowly, as sufficient raking capacity may not be secured, and an accumulation of solids is likely to build up to such a depth that the arms will be compelled to push the solids ahead of them. This would mean that the thickener was overloaded, notification of which would be given the operator by the overload alarm.

The Thickeners vary in size from small laboratory machines up to those 200 feet or more in diameter and may be constructed of iron, wood and lead or other materials.

Filter Press Pumps.—There is nothing connected with filter presses that is more important to have exactly right than the pump for handling the material to be filtered.

The ordinary pressure pump will serve for many purposes, but if the material handled contains grit, gum, mud or any particles that may get under the valves and stay there, the pump is soon put out of commission.

Pumps should be especially adapted to filter press work. The valve seats should be designed so as to minimize the possibility of clogging and, when trouble does occur, it is only a matter of a moment to get at the valves, remove the obstruction and continue pumping.

No one who has not had experience can realize what trouble can be caused by using pumps which are not designed for the particular use with filter presses.

Figure 247 shows a vertical, triplex, belt-driven pump used to a considerable extent with plate and frame filters where steam is not available, and Figure 248 shows the Duplex steam pump employed where it is more convenient to use steam. Either the piston or ram type is used according to the material to be pumped.

There are many cases, however, where it is necessary, owing to the character of the material to be filtered, to use other means than a pump to force the material into the filter press. If gravity pressure is not sufficient, the best method is the Montejus or

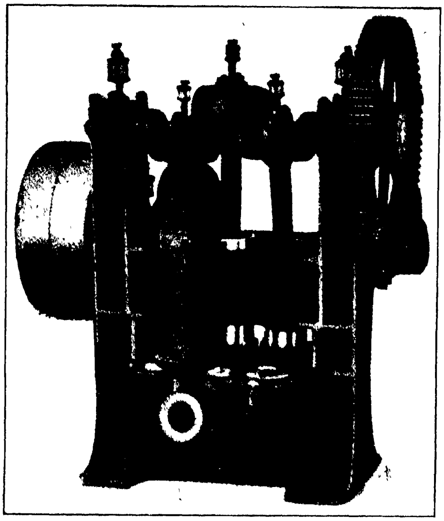


Fig. 247
Vertical Triple Pump

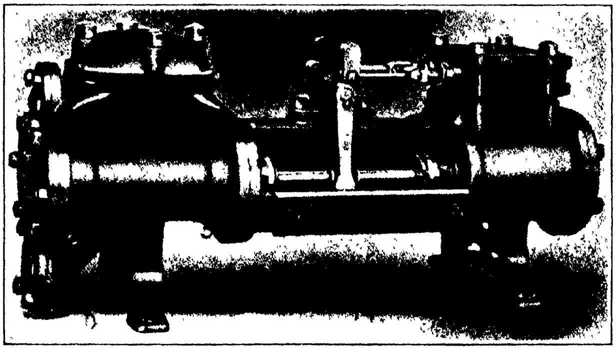


Fig. 248
Duplex Steam Pump

pressure tank and an air compressor. Many are employing this method of operating their filter press with the most satisfactory results.

The Johnson Filter Press Pump, for instance, is especially designed for operating filter presses. It can be mounted on the head of the filter press, Figure 249, where it requires no additional floor space, or may be mounted on a separate column, as shown in Figure 250. It is hand made, belt, motor and steam driven. For acid solutions, diaphragm chambers directly connected below the plunger pump are used. These may be lined with lead or other non-affected metals. One of the especially valuable features of these pumps is the automatic pressure governor, which allows a gradual increase in pressure in the filtering chambers.

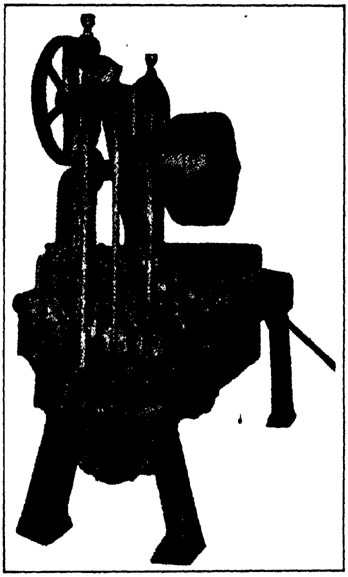


Fig. 249
Mounted Filter Press Pump

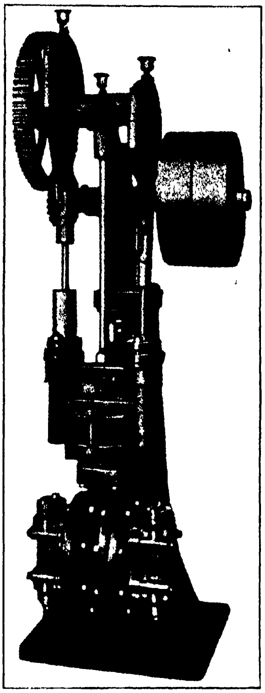


Fig. 250
Filter Press Pump

On leaf filters of the Kelly, Sweetland and Vallez type the most successful pump is the open impeller centrifugal pump. This open impeller type allows the pump to handle muddy, sandy or gritty solutions. A view of one of these pumps is shown in Figure 251.

With suction filters there are three kinds of pumps used to create the vacuum, wet vacuum pumps, dry vacuum pumps and hydro-turbine pumps. The wet vacuum pumps, Figure 252, are employed with open tank filters where the cake does not crack badly and with rotary filters where the cake is dense and com-

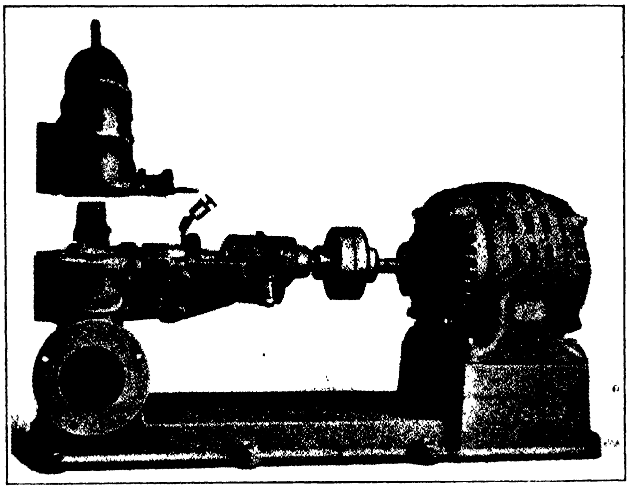


Fig. 251
Centrifugal Pump

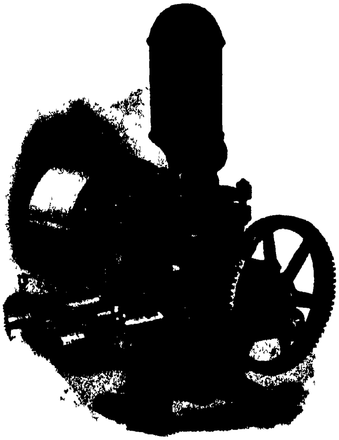


Fig 252
Pyramid Wet Vacuum Pump

pact. This is for the reason that if any cracks occur the air will rush through and form air slugs in the pump thereby destroying the vacuum.

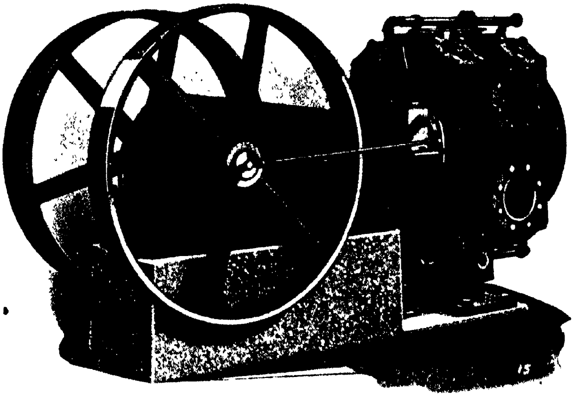


Fig. 253
Dry Vacuum Pump

Where any quantity of air must be drawn through the filtering medium dry vacuum pumps, as illustrated in Figures 253, 254, 255 and 256, are used.

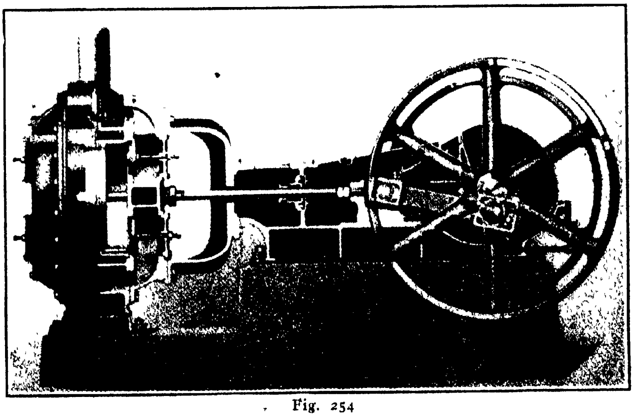


Fig. 254
Dry Vacuum Pump

With them of course there is the necessity of using an intermittent receiving tank between the pump and the filter. This in order to make the operation entirely continuous also means

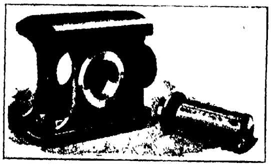


Fig. 255

a rotary pump, Figure 257, or a centrifugal pump, Figure 251, must be used to continuously discharge the receiving tank (unless a barometric leg can be employed). Dry vacuum pumps are used for rotary filters, rotary hoppers, dewaterers and open tank filters.

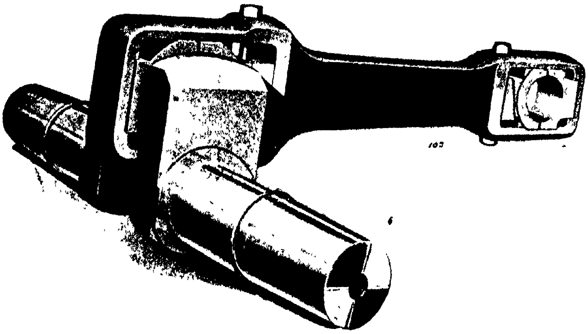


Fig. 256
Connecting Rod

Hydro-turbine pumps, Figure 258, are employed where it is desired to draw air and water through the pump at the same time. This is an ideal arrangement for non-corrosive materials but unfortunately warm or hot solutions can not be handled and 10 to 12 inches of vacuum is about all that can be depended upon.

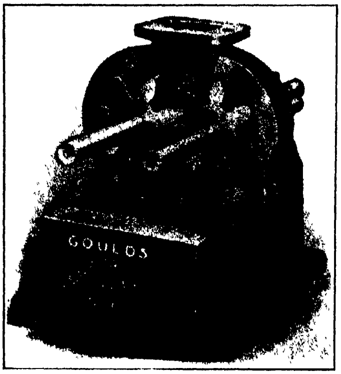


Fig. 257
Rotary Pump

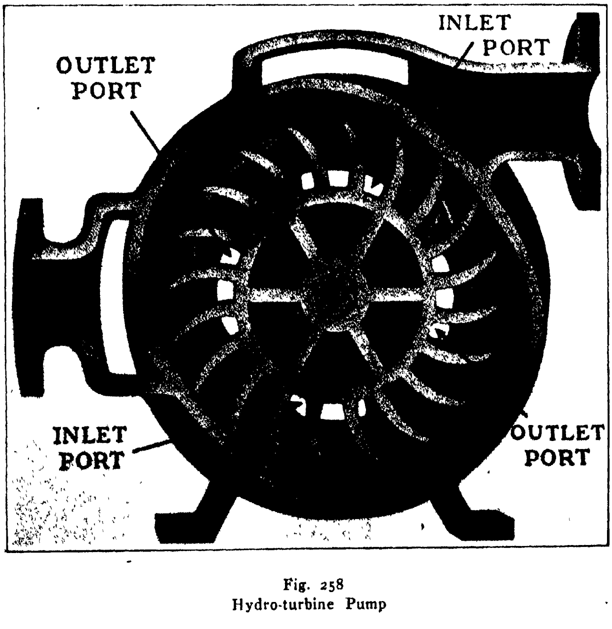


Fig. 258
Hydro-turbine Pump

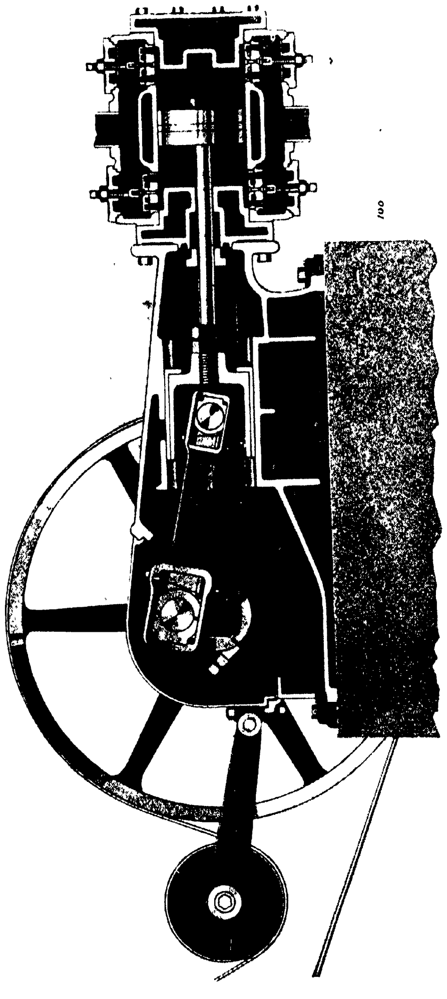


Fig. 259
Sectional View of Compressor

Compressors are used for giving compressed air for discharging the filter cake in vacuum or other filters if steam or water is not employed. A horizontal type is illustrated in Figure 259 and a vertical type in Figure 260.

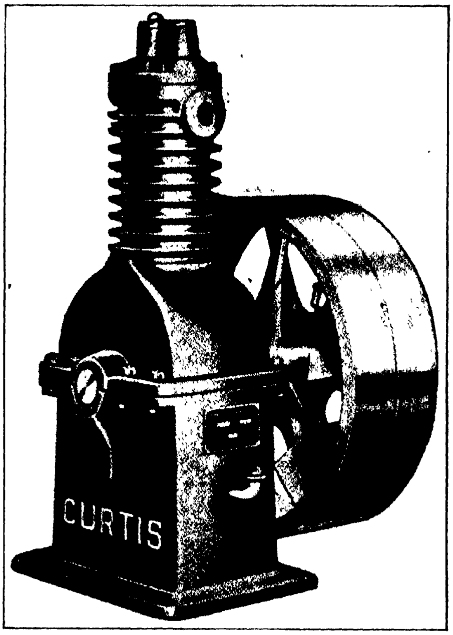


Fig. 260
Air Compressor

Strainers in Connection with Filter Presses.—One of the most important accessories to a filter press outfit and one that is most often overlooked is a strainer.

This is a device which is either put in the line of pipe between the pump and the filter press or on the suction end of the pump, to keep out material which might otherwise clog the channels of the filter press or the valves of the pump.

In case the valves of the pump are clogged, the pump must be stopped, the valve caps taken off and the obstruction in the valve removed, causing inconvenience and loss of time.

If the filter press channels become clogged, there is great danger of one or more filter plates being broken. In fact, this is one of the principal causes of broken plates in a filter press.

Cloth Washer.—The Manguin Filter Cloth and Bag Washer is a typical washer used to some extent abroad for washing the cloths from plate and frame filters and the bags from leaf filters.

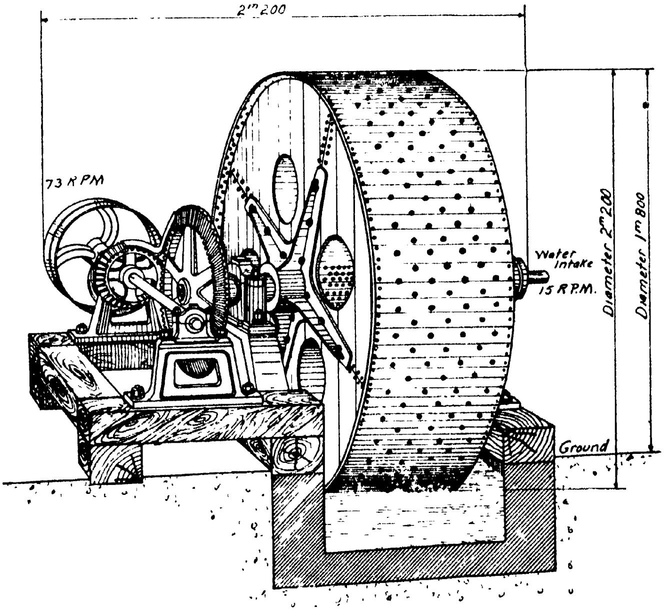


Fig. 261
Manguin Filter Cloth Washer

From Figure 261 it will be seen that the drum is divided into four compartments, having lateral openings. The filter cloths or bags are charged and discharged through these openings.

The number of cloths or bags washed at one time, depends upon their size, as the compartments must be only half full to allow their being thrown around freely.

The water must enter under pressure, through the central intake, in sufficient quantity to thoroughly wet the bags or cloths.

As will be seen from the drawing, the lower portion of the perforated drum, revolves in a tank of masonry or concrete, which is provided with an overflow for the dirty water. The drum is made to turn for a longer or shorter time, depending on how dirty the cloths or bags are. In general and under normal conditions about four operations can be completed per hour.

Pulp Washers.—A pulp washer that is used in connection with filters that use paper pulp as a filtering medium is illustrated in Figure 262. The washer is used both in Europe and America in some of the sugar refineries especially in connection with the Perrin Filter Presses.

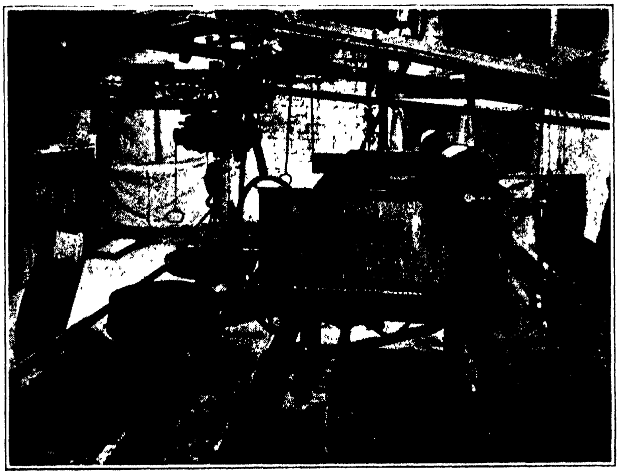


Fig. 262
Paper Pulp Washer

The washer consists of a tank, into which the pulp is put as it is removed from the filter. At the bottom is an enclosed archimedes screw open at both ends which is driven by the pulley

"A" at four hundred revolutions per minute, the pulp and water together being drawn from the front to the back of the tank, and thereby thoroughly agitated. By so doing all the solid, gummy substances, etc., are separated and are either dissolved, or held in suspension by the water. This water passes continually through the fine perforations of a copper drum "B" made to rotate by a counter shaft, thus skimming the water as it were, but not allowing the fine particles of floating pulp to pass out.

This dirty water leaves the drum "B" at the opposite side to the one shown in the cut, and finally finds its exit through the pipe "E." The water so evacuated is replaced by clean water.

By this vigorous agitation, the pulp is continually held in suspension in the water, and when the water coming from the drum is clear the contents of the washer is run out into a dewaterer through the rubber hose "D," after opening the cock "C." The pulp is then clean and in a condition to be used again. Pulp can be cleaned and used in this way many times.

A more efficient method of washing the pulp is by means of a series of rotary hopper dewaterers (described in Chapter II). The pulp to be washed is fed to a dewaterer washed and discharged as a semi-dried cake into a mixing tank where it is repulped and sent to a second machine, etc., until the pulp is clean, three machines usually being enough. By this means a great deal of time is saved and the amount of water necessary for washing is cut to a small percentage of that otherwise required.

Filter Aid Recovery.—The recovery of filter-aids is an important item where such recovery is possible.

Inert filter-aids are usually recovered by burning, a good example of this kind of recovery apparatus being that employed for spent Oleite.

The simplest method involves the use of a Tray-Type Kiln. The upper, or tray section of the kiln, should contain the spent material to a depth of from 2 inches to 4 inches. If the latter depth is used a tray will contain about 6 cubic feet or 300 pounds.

The tray should be covered with fairly snug fitting iron doors, or at least with a sheet of light iron, to prevent oxidation with an oxidizable substance. A wood or coal fire should be maintained in the fire box until all moisture has been expelled and the temperature of the spent material raised to a low red heat. It should stand at that temperature for about 4 hours, after which it may be cooled by drawing the fire or banking it. Under no circumstances should the flame or heat come into direct contact with the filter-aid, and circulation of air at its surface during the process of burning should be avoided.

The cover should not be removed until the red heat has entirely disappeared from the material, when the latter may be removed, cooled and screened to extract the dusty products of reduction.

To test the material, take a small quantity (about a tablespoonful)in the palm of the hand and pour on it a few drops of water; if the latter penetrates readily, it indicates that it has

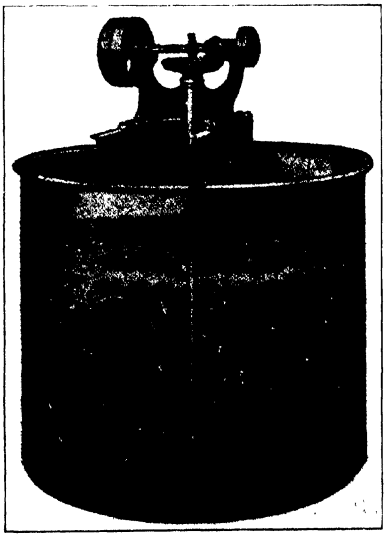


Fig. 263
Mixing Tank

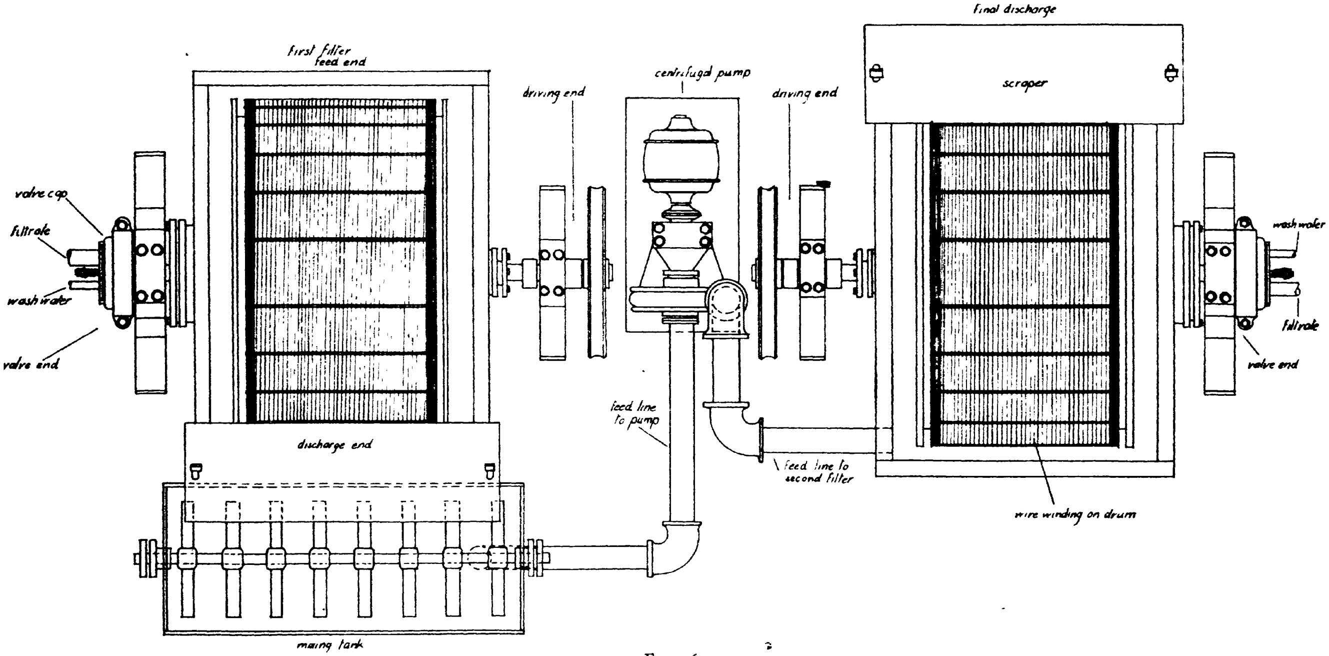


Fig. 264
Rotary Filter with Repulping Tank

been sufficiently reburned, but if the water rolls off, or stands up in globules, it should have further heat treatment. If any difficulty is experienced in mixing water with the recovered material, it indicates insufficient reburning.

Mixing Tanks.—Figure 263 illustrates one of the newer forms of mixing tanks. Such a mixing tank may be used prior to filtration or interposed between filters for repulping.

The great advantages of complete and thorough mixing have been particularly brought out in concrete work. The same general benefits however, can be derived, no matter what the material is that must be mixed and consequently there are many opportunities for investigation work along this line particularly in connection with filtering and washing.

Repulping tanks are often employed where a number of rotary hopper dewaterers or filters are used in series or tandem Figure 264. This is especially true where one filtering and washing will not give a clean cake.

CHAPTER IX

LABORATORY FILTERS AND SPECIAL APPARATUS

Laboratory filters are unquestionably an absolute necessity for analytical work or technical research, but the very fact of their being such an indispensable part of laboratory equipment has often caused insufficient attention to be paid to the fine points in their operation. For instance, filtration by means of filter paper and a glass funnel is so simple that very little attention is given to the possible means of improving its efficiency, yet if the paper is folded properly and the top corner tore off diagonally across the entire quadrant, a very tight joint will be made between the top of the paper and the glass, so that danger of leakage by filling the funnel above the top of the paper is avoided and there is no difficulty in the final washing down of particles of precipitate from the glass onto the filter. There might be cited numerous other "tricks of the trade" whereby the ease and accuracy of the operation could be increased, not only in glass funnel filters but in Gooch filters and Buchner funnels, and it will be well worth the while of anyone engaged in work requiring filtration of this kind to thoroughly investigate the possibilities of the filtering apparatus.

Beside the cone filters, funnel filters, filter tubes, gas filters, Gooch filters, Buchner funnels, Bergfeld filters and Pasteur filters there is semi-commercial equipment which is of great importance to large plant laboratories, industrial laboratories, technical schools, and filter manufacture laboratories. This equipment consists largely of commercial apparatus such as filter presses, rotary filters, leaf filters, and stationary filters, in small sizes. Some of the semi-commercial equipment of course is not made or adapted for large installations but these machines are rather the exception than the general rule and are but few in number when compared with the former type.

Laboratory Filters—The Buchner funnel (Figure 144) and the straight funnel (Figure 145) are familiar to all who have had any laboratory experience as is the Gooch filter (Figure 146).

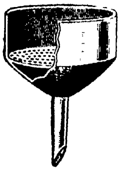


Fig. 144
Buchner Filter

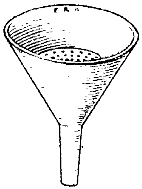


Fig. 145
Funnel Filter

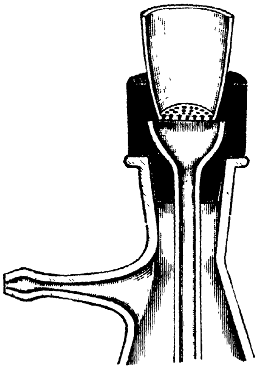


Fig. 146
Gooch Filter

In the first two a filter bed of paper or cloth is generally employed while in the last asbestos is commonly made use of. The application of suction enables filtration to take place with fair rapidity and quantitative results are obtained. The alundum cones (Figure 147) are often used for filtering finely divided solids, as glass wool, paper pulp, asbestos, clay, make quantitative accuracy difficult by allowing impurities to occupy the space between the grains. The alundum cone is in itself fine enough to act as the filtering bed and yet can be easily weighed to determine the precipitate. It has the objection, however, that clogging often occurs and there is some absorption of atmospheric moisture. This is likewise true of unglazed porcelain and tripoli filters (Figures 148 and 149).

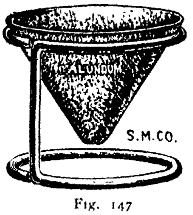


Fig. 147
Alundum Cone

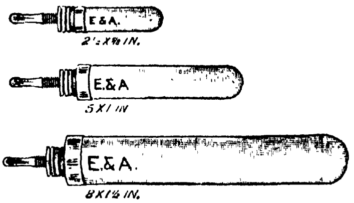


Fig 148

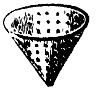


Fig 149

Porcelain Filters

In the microscopic analysis of water by the Segwick-Rafter method the greatest percentage of error is found in the examination of those waters which contain a large number of delicate protozoa. There is hardly a surface water which does not contain some of these organisms and the impurities are often largely made up of them. In ordinary filtration, the drying out of the sand in filtering and a change of media by the use of distilled water for washing kills the protozoa immediately. Centrifuging as taken up on page 190 also shows bad results except for volumetric determination of impurities in water for fish interests. For this reason a special filter must be used to obviate the two above mentioned causes of the death of the protozoa. The filter consists of by-passes for keeping the medium wet and inoculated water for washing, as the pellets of such filters as used in Pasteur and Bergfeld filters (Figure 150) will operate too slowly for practical purposes in this work. Some special laboratory filters are the tincture filter (Figure 151) and the gas filter for dust collection (Figure 152).

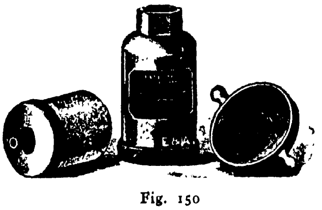


Fig. 150
Bergfeld Filter

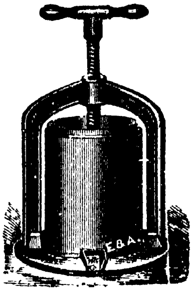


Fig. 151
Tincture Filter

Fig. 152
Gas Filter

Laboratory Centrifuges—The laboratory centrifuge has a normal speed of 40,000 revolutions per minute in the super-centrifuge type and a much lower speed in the other styles as the water motor centrifuge illustrated in Figure 153. The centrifuge

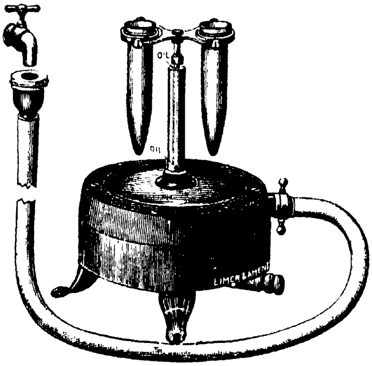


Fig. 153
Laboratory Centrifuge

is used in the refining of oils, preparation of organic and inorganic compounds, the recovery of by-products, for laboratory data, etc., and in bacteriological laboratories. In this last case a large quantity of clear agar agar solution can be obtained in a few minutes even when a poor quality of agar agar has been used. Blood serums, after being run through a centrifuge are clear as water and liquids can be freed from suspended bacteria by this means which is much better than a Bergfield filter will do.

The machines may be either hand-driven, electrically-driven or water-driven, as desired, and they have proved to be of great value to the laboratory both for actual separation purposes and for estimating the settling rate of slurries. This last is accomplished by the commonly called whizers (Figure 153), in one side of which is placed a given quantity of slurry of known settling rate and in the other side, the same quantity of an unknown slurry. A graduated tube enables the operator to read off the rate, after whizzing, by comparing the settling of the unknown with the settling which has occurred in the known slurry tube. The settling rate, if good, indicates the filtering rate will likewise be good and thus the apparatus is of value for laboratories investigating filtration problems.

Semi-Commercial Filters.—Semi-commercial equipment is used by large industrial laboratories, manufacturing plant laboratories, large technical schools, and by the filter manufacturers. The machines used are almost identical with the apparatus of commercial size and this is a necessity if the results obtained from experiments with them are to be taken as criterions of what may be anticipated on a large scale.

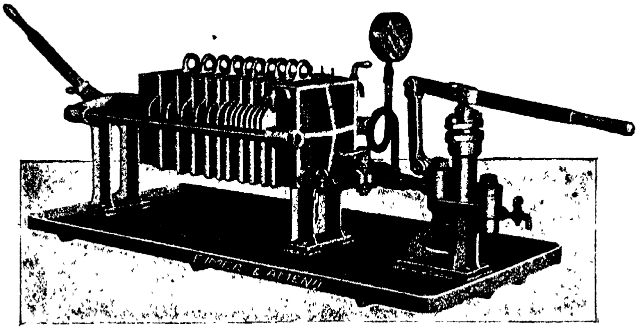


Fig. 154
Laboratory Plate and Frame Filter

Before making recommendations or deciding as to the best type of filter to employ for any proposition it is always desirable to run laboratory experiments on the particular material in question. There are many variations in plant practice, raw material, etc., which although they may be small enough in themselves nevertheless, can cause decidedly different filtering results to be obtained. For this reason both industrial laboratories and filter companies maintain various semi-commercial filter equipment for testing purposes.

Some of the commonly employed laboratory filters of the type just mentioned are illustrated in Figures 154, 155, 156, 157 and 158.

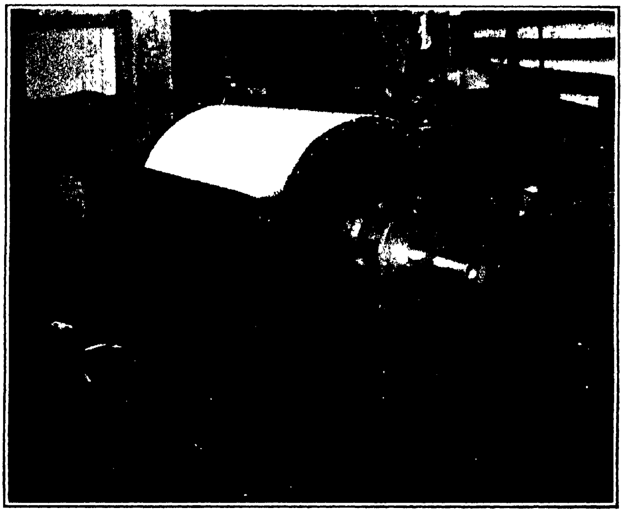


Fig. 155
Laboratory Rotary Filter

The Vallez Laboratory Filter illustrates a very convenient filter for either clarification or when the operator wants to save either the filtrate or cake or both. In Figure 156 it will be seen

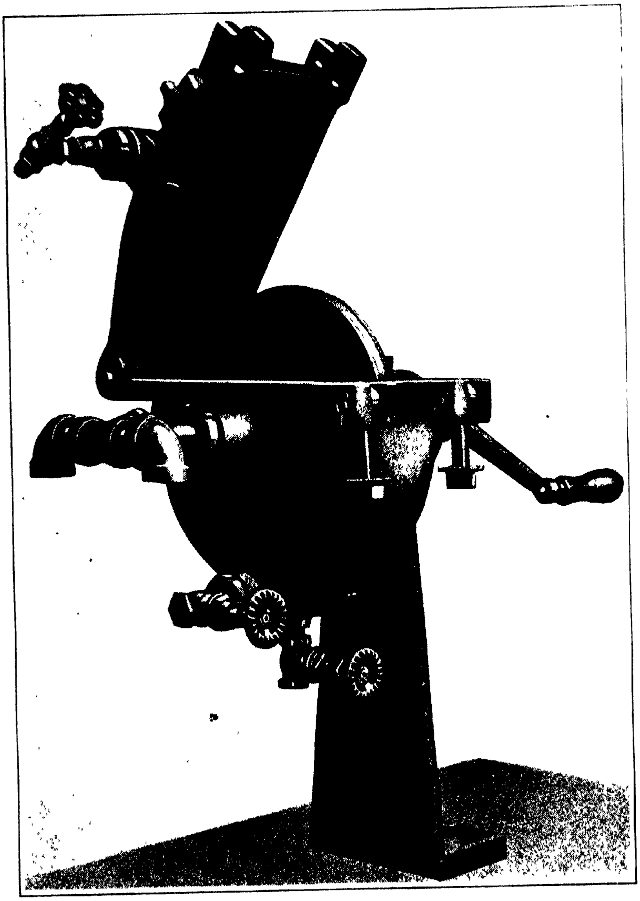


Fig. 156
Vallez Experimental Filter

that the filter is made of cast iron, or any other suitable metal according to requirements, and mounted on a standard. This filter can be located anywhere in the laboratory or plant for experimental work. It has all the connections and operates the same as larger Vallez Filters and has a unit of filtering surface, one square foot, so that calculations are easily made. The illustration shows that the filter medium can be turned by hand or a pulley may be attached if power is desired.

Figure 156 shows the filter open so that the cake may be examined, and the filtering element removed if desired. The illustration shows a cake of paper pulp on the leaf. This filter is used for the complete operation of filtering and washing of the cake. Separate discs with different grades of filter cloth or different mesh wire cloth may be kept on hand and inserted in a few minutes' time. The filter is built with one or more leaves as desired and can therefore be used for semi-commercial operations.

The Zenith Open Tank Filter (Figure 157) is often used by employing a single leaf 3½ inches long by 3½ inches deep. Such a leaf, in operation is submerged in a battery jar containing the material to be filtered, connected by rubber tubing to a Winchester bottle and the bottle in turn connected to an aspirator, pump or other suction line. Washing may be accomplished by transferring the leaf and adhering cake to a jar of clear water. The results obtained are directly proportional to the area as the time and vacuum remain the same whether for large or smaller areas. The results may also be taken as an estimate for rotary filters, as the leaf can be compared to a single compartment of the rotary filter and the time of submergence, time of washing, time of drying and time for discharge totaling one revolution of the filter drum.

In general the method of operation and interpretation of results from laboratory filters is directly proportional to the area employed although in calculating large installations it is wise to allow a 15 or 20 per cent margin of safety to cover any errors which although they are insignificant on a laboratory scale, when magnified a great many times for commercial use may prove to be very serious.

One of the greatest sources of error in laboratory filtration is in the preparation of the filter for the tests. If the filter has been used for other materials it must be thoroughly cleaned, especially

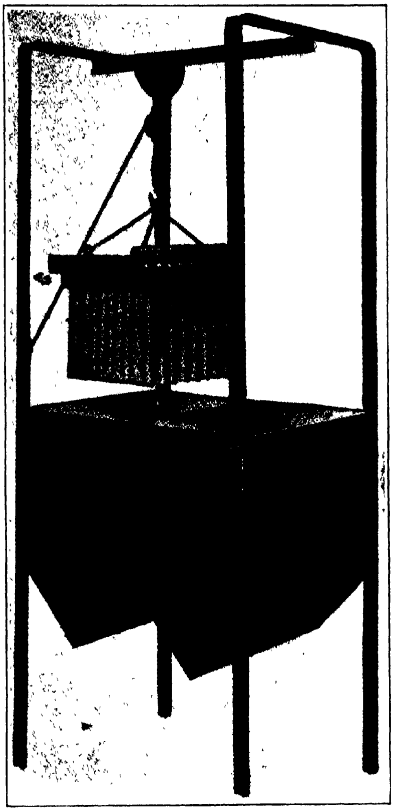


Fig 157
Laboratory Open Tank Filter

the filtering medium, as the remnance of slimy material will cut down the rate of flow of a relatively free filtering slurry and vice versa, and a small amount of finely divided solids may cause a cloudy filtrate and consequently the selection of a closely woven filter cloth which is unsuited for the work. On the other hand when a filter is either new or very clean several runs must be made to get reliable figures as the first trial after cleaning or renewal of cloths gives much better results than will be obtained over a period of time. Wherever possible tests of several days at least should be made as there are always adjustments necessary which are much easier to make on the laboratory machine than on a large filter. The information sheets sent out by filter companies, samples of which are shown from pages 196 to 203, etc., if filled out and returned to the companies enable them to run their experiments intelligently and the laboratory reports illustrated on page 201 show how the results of the tests are tabulated.

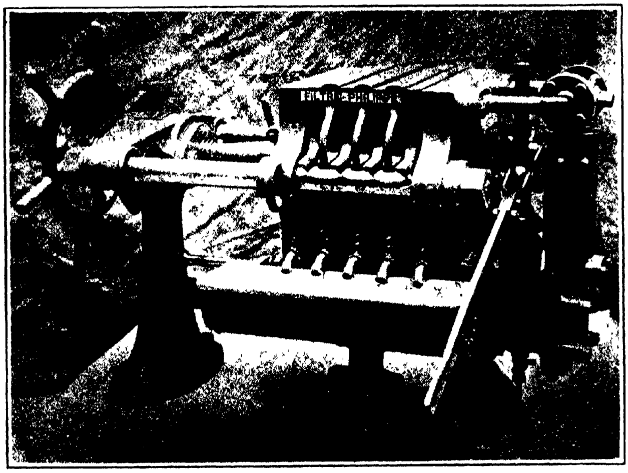


Fig. 158
Laboratory Plate and Frame Filter

SAMPLE INFORMATION SHEETS

WATER FILTERS

Data Wanted

In writing for information please furnish data on the following points:

1. State whether supply is from a creek, river, wells, lake or impounding reservoir.
2. Is the water generally turbid or roily?

3. Is it turbid or roily only after rains?
4. Is it considered hard or soft?
5. Is it discolored or stained?
6. Is the sediment light or heavy?
7. Does the sediment settle out quickly, or does the water remain turbid or roily after several hours' standing?
8. Does it possess at any time a disagreeable taste or odor?
9. Is it contaminated with sewage?
10. What objectionable feature is it most desired to remove from the water?
11. What is the maximum quantity of water to be filtered per hour, or in ten hours, twelve hours or twenty-four hours?
12. If the water supply is pumped, state how many pumps are used, and give the capacity and type of each.
13. State diameter of suction and discharge mains.
14. State the domestic and fire pressures carried on the mains in town and at the pumping station.
15. If water is pumped to a standpipe or reservoir, state capacity and elevation of high-water level in reservoir or standpipe above pump-room floor.
16. Are pressure or gravity filters preferred?
17. Do you pump from an intake or wet well?
18. What steam pressure is carried on boilers?
19. How far is pump station or filter site from nearest freight station, and are roads good or bad, flat or hilly?
20. If electric current is available for operating machinery, state whether it is alternating or direct, and give voltage, phase, frequency, cycle, etc.
21. What is the local price for best American Portland Cement?
22. What is the local price for good building brick?
23. Must bonds be voted to provide funds for building filter plant?
24. Must question of building filter plant be submitted to vote of the people?
25. What is the population of the city or town to be supplied?
26. How much ground area is available to accommodate filter plant?

27. What is the nature of the ground—sandy, shale, filled, hard clay or rock?
28. If the ground ever becomes flooded, state to what depth.

FEED WATER FILTERS

Kindly answer as fully and definitely as possible the following questions.

Name of Owner or Company. . . . .
Address . . . .
Give size and description of your boiler plant. . . . .
. . . .
Give description of your engines and pumps . . . .
. . . .
. . . .
☞Give amount of feed water used per day. . . . .
☞What is the cost of your feed water per 1,000 gallons or cubic feet? (and state which). . . . .
State number of hours per day under steam. . . . .
Do you exhaust into a surface condenser; —if so, how much horsepower? . . . .
What is the temperature of your returns? . . . .
Do you heat by exhaust steam;—if so, how many weeks in the year? . . . .
For what other purpose do you use exhaust steam? . . . .
Do you have an open or closed heater?. . . . .
What is the cost of your boiler compound per year?. . . . .
How often do you clean boilers?. . . . .
How much oil per day do you feed to your cylinder?. . . . .
☞Do you now feed your oily returns into your boilers?. . . . . .
☞Have you an oil-extractor in your exhaust-pipe?. . . . .
Do you collect all of the returns in a tank? . . . .
What is the vertical height of the bottom of the collection tank or point of collection of the returns above the suction of your feed-pump? . . . .
What is the horizontal distance between the point of collection and the feed pump? . . . .

☞What is the diameter of suction on the feed-pump?........

How much make-up water do you require?..............

If possible, give us a sketch illustrating the above on the back of this sheet.

(Signed)

CHEMICAL FILTERS

Kindly fill in as many of the following spaces as possible in order to facilitate recommendations.

1. Name of manufacturer..........................
2. Address of manufacturer..........................
3. Nature of solids..........................
4. Nature of liquids......... Per cent acidity.......
   Per cent alkalinity......., neutral............
5. Quantities of material to be handled per day of...... hrs.:
   gal..................., tons..................
6. Would the quantity of material fed to the machine vary during the day?..........................
7. Percentage of solids to liquids..........................
8. Does the amount vary?..........................
9. Do you wish to wash the cake?..........................
10. Amount of wash water allowed?..........................
11. Can fractional washing be employed?..........................
12. Can excess wash water be used for mixing new batches?.....
13. Filtering temperature.....C..........F.
14. How is your material being handled at present?........
    What is your filtering medium?..............
    Rate of flow.... Pressure.... Thickness of cake...
    Have you vacuum?...... If so size of pump........
15. Is your material colloidal?..........................
16. Can it be settled or thickened?..........................
17. What materials may be used in constructing apparatus?..
    ....
18. Will you forward a five-gallon sample for test in our laboratory?..........................

By..

....

CENTRIFUGALS

Questionnaire

1. What is the material you propose to handle?....... .....
2. Nature of material?..................................
   Specific gravity or weight per cubic foot of material—. ....
   Crystals? .. ..
   Fibres? .. ..
   Sludges? .. . .
   Liquids? ....
3. Weight per cubic foot of your material when dry......... .
4. What degree of dryness is required in the centrifuged material? . ...
5. Do the crystals, fibres, sludges, etc., have to be washed in the centrifugal? ... .
6. What is the nature of extracted liquor?... . ...
   Specific gravity? .. . . What acid or alkali?... .. ...
   Acid? ....
   Alkali? .. ..
7. Does liquor have to be saved?.. .. .. Protected from contamination? ....
8. Quantities of mixture to be handled per day of......hours.
9. Ratio of solids to liquids in mixture or ratio of materials to be separated.. . . ..
10. At what temperature will material enter the centrifugal?....
11. If possible forward sample of material for our inspection and testing. ....
12. State precautions to be taken when handling the material to prevent injury to persons and apparatus.

Signature ....

DUST PROBLEMS

Questions to be answered and information required.

1. Nature of dust. ....
2. (a) Is dust dry or moist?.............................
   (b) Approximate temperature ....
3. Name number of elevators, conveyors, bins and machines of all kinds where dust originates and fogs out into plant....

....

4. Have you a dust collecting system in at present?.. ....
5. If you have a fan, name size, style and speed, also give dimensions of inlet and outlet of fan.......... ....
6. Name or designate on a sketch, the most available spot to place fan and dust collectors.... . .. .
7. Kind of power to drive fan. Whether electrical or mechanical. ....
8. (a) Approximate weight per cubic foot of dust... .. ...
   (b) Approximate tonnage per hour.... . . . ...
9. If fan is to be driven from line shaft, kindly give speed of shaft and direction runs... ....
10. Do you want our representative to call on you?. . . ...
11. If possible, send blue print of building, where dust collecting system is to be installed.

LABORATORY REPORT SHEET

Filtering tests made for ....

Address ....

Samples received by.. . . . on.. ....192..

Percentage of solids to liquids .. . .

Nature of solids ....

Nature of liquids ....

Quantity of sludge to be treated per day of.... .hours........
gallons .... pounds........ ... .

Date of test........ . .. 192.. . By... ... .

Filtering temperature......C.... ..F. Vacuum........inches.

Style of filter .... Size of filter..... ....

Filtering medium ....

Minutes of one cycle ....

Minutes of actual loading....Amount of filtrate....cc.....gals.

Minutes of washing ......Amount of wash......cc.......gals.

Minutes of drying ....

Thickness of cake...............Area of cake...............

Weight of cake....g.....lbs. Weight of dry cake....g.....lbs.

Moisture content of cake................

Does cake crack?......If so, when?.......

Character of cake......................

How does the cake discharge?.........

Rate per sq. ft. per cycle of......hours.

Filtrate........gals. Wash.......gals.

Wet cake.......lbs. Dry cake.......lbs.

Type of apparatus recommended.........

Size of apparatus recommended..........

Comments:..........................

....

....

RATE OF FLOW PER SQ. FT.

Time	Filtrate

SPECIAL APPARATUS.

Bag Filters.—In sugar filtration bag filters such as the Taylor and Buflovak are still used a great deal. (Danek and Phillippe are considered as leaf filters because of their rigid frame).

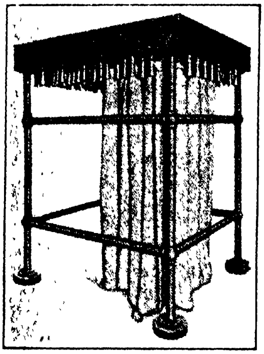


Fig. 159
Bag Filters

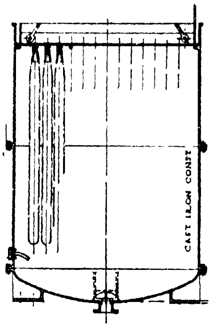


Fig. 160
Bag Filters—Cylindrical Type

The bag filters (Figures 159 and 160) are constructed in rectangular and cylindrical types and may be arranged to permit removal and replacement of bags by means of removable heads. In the rectangular type the head consists of two parts which are changed alternately thus avoiding any interruption in the operation of the filter.

In the cylindrical type the entire head and bags are removed from the filter body and replaced by a new head and set of bags, thus reducing interruptions to a minimum.

Provision is also made to prevent a falling bag from closing entirely the discharge opening.

Drain-Off Filters.—A special type of filter which is used both in laboratory work and by some manufacturing plants is the drain-off filter or as it is sometimes called the Nutche Filter. It consists of a rectangular round-bottomed tank made of wood, lead, iron or other material which tank has perforations on all four sides and on the bottom. A cloth is laid over the tank and caught down on the edges and the material to be filtered is thrown in and allowed to drain through by gravity. The solids can be removed by simply taking off the filtering medium as a whole and the medium can be readily washed and cleaned.

A filter of this kind is of use where materials drain rather freely, are not in abundance, and where time is not an important item. It obviously cannot be used where large capacities are desired, where labor is scarce, or where quick filtering is necessary.

Karl Kiefer Filters.—The filters manufactured by The Karl Kiefer Machine Company, called Karl Kiefer Filters, are similar to those of the International Filters Company described on page 76. The filters are made up to 1,000 barrels per day capacity, although the smaller types have capacities only up to ten barrels per day. They are used for fruit juices, syrups, tonics, perfumes, toilet water, etc., and depend for a filtering medium upon a bed of cotton compressed into plates by the operator just prior to the use of the filter.

The filters may be made up in a series of filtering plates (Figure 161) or may be used as a single unit (Figure 162). A small packing apparatus is furnished with each filter so that

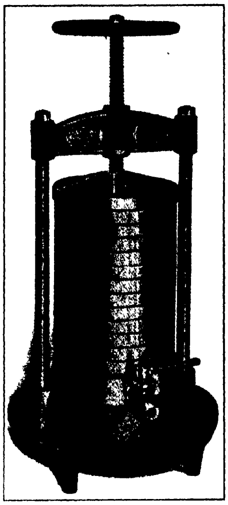


Fig. 161
Karl Kiefer Filter

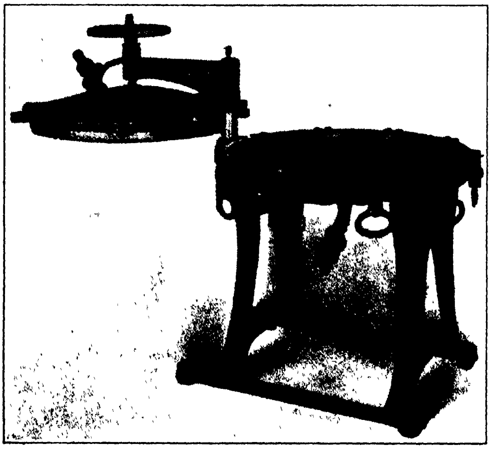


Fig. 162
Karl Kiefer Filter

plates of the desired thickness may be built up. The thickness of the plate is from one-half an inch to one inch. The inlet of the filter connects to the faucet on the cover and the liquid flows by gravity through the filtering medium and is discharged at the bottom. When the filter layer becomes so clogged that the rate of flow almost ceases it must be replaced as it cannot be cleaned in the machine. In other styles of the Kiefer filters a paper sheet or cloth pad may be used as the filter medium. Some of these styles are similar to the pulp plate filters while others are tray filters (Figure 163).

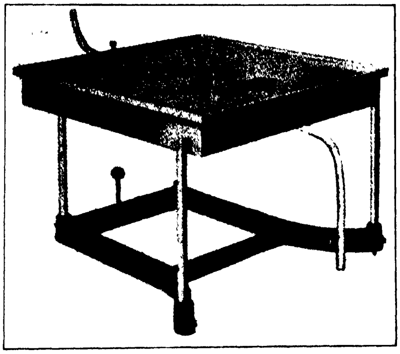


Fig 163
Tray Filter

The construction materials may be bronze, copper, block tin, etc., as the occasion demands and the paper or cloth medium is suitable for any material which will be handled by this apparatus.

The apparatus is very simple in construction and requires no power for operation. It can be unpacked, cleaned and re-packed in a short space of time and the pulp plates give clarity of filtrate and more rapid filtration than sheets of prepared media. There is of course the trouble of making up the pulp plates and the labor of replacements if the material to be filtered is very dirty while the use of gravity necessarily means limited rate of flow.

Zeit Filters.—Recently a good many pharmaceutical manufacturing plants have installed Zeit Filters for clarifying purposes.

These filters are practically the same as the Phillipe filter described in Chapter II. They are however only for clarifying, as the filtering medium is a screen of about one hundred-mesh it being necessary to add ground asbestos to obtain a clear filtrate. The operation is by gravity and the asbestos which is mixed with the slurry readily forms a compact free filtering mat on the filter screen. The capacities given by such a filter are large for this class of work and complete batches can be run. It is not as efficient however as many other leaf filters and the cost of specially ground asbestos is very high.

Radio Filter.—As radio communication is very popular at the present time and of universal interest it might be well to mention in conclusion the electrical filter invented by Dr. G. A. Campbell which makes it possible to separate the various frequencies at which the individual telephone and telegraph messages are carried. Telephone and telegraph messages are carried simultaneously from a single wireless transmitting set and antenna and they are received by a single radio set without interference or distortion. The messages are detected by a single vacuum tube circuit, after which, they are passed through the filter which separates the frequencies of the telegraph message from those of the telephone messages. The filter differs materially from the ordinary tuned circuit familiar to radio engineers, as the filter separates not single frequencies, but bands of frequencies of any predetermined width. The filter makes it possible to separate bands of frequencies comprising the telephone message from the band comprising the telegraph message and in addition it can separate one telephone message from another.

CHAPTER X

PLATE AND FRAME PRESSES

Filter presses are used in the filtering of a greater variety of materials than any other class of filters. They possess the one great advantage of force to compel the separation of solids from liquids, which separation in many cases could not otherwise be accomplished economically. Although semi-colloids, flocculents and similiar materials often simply become imbedded in the mesh of the filtering medium, and continued increasing pressure only serves to make the medium more impervious by packing the solids more tightly together, there are numerous propositions where this does not occur despite the fact that vacuum or low pressures gives almost no rate of flow.

The filter press may be described as a frame in which a number of loose plates of filter surface may be clamped together to form a series of hollow chambers capable of withstanding internal pressure, the filter surface being ribbed or grooved and covered with cloths. This arrangement of course is capable of modification to meet varying conditions called for by different grades of material, both as regards thickness of cake, suitable pressure, varying filter media and the arrangements for washing or steaming the cake when formed. The rims of the plates are raised so that when two plates are brought together a hollow chamber is formed between them, while the cloths are laid over each side of the plate.

The regular iron plate press consists of a frame made up of two end supports, rigidly held together by two horizontal steel bars. Upon these horizontal bars are placed a number of recessed plates or flush plates and frames, clamped together, thereby forming the hollow chambers. The faces of these plates are grooved, pyramided, or ribbed, as the case may be, except at the edges which are machined to form a joint surface. The whole plate is covered with cloth, forming a filtering surface where the plate is grooved, pryamided, or ribbed and acting as a gasket on the machined surface. A screw fitted with a closing device for pressing the plates or plates and frames together is situated on one end of the frame and operated against a movable head. On the other end of the frame is a fixed head. The plates and frames are pushed along horizontal bars by hand when putting on or taking off the cloths or when discharging the cake or closing the press.

Two forms of plate presses are in general use; recessed plate, and flush plate and frame presses, or as they are sometimes known, chamber presses, and frame presses. Either of the types may be made in circular, triangular or square form.

Of the two types of plate presses the recessed press is the simpler in construction and it therefore will be taken up first. The cake is formed in the hollow chamber between two recessed plates, the thicker edge of the plate forming the joint surface. The feed passage is taken through the body of the plate, while the filter cloths are laid over each side of the plate, forming a pressure-tight joint at the rims when clamped up and having holes for the feed passage. The cloths are either sewed or clipped to make a joint at the corresponding hole in the plate. The round and the square type of recessed plate presses are shown in Figure 164 and 165, respectively.

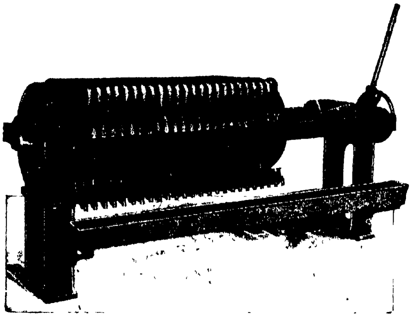


Fig 164
Round Plate and Frame Filter

Figure 164 shows the circular, center feed, open delivery non-washing type of recessed plate filter press. The plates are shown at "A," moveable head "B," fixed head "C," plain iron outlet bibbcocks "D," filtrate trough "E," feed "F," and locking mechanism "G."

The operation of this filter is similar to that of the square press and therefore need not be taken up here. Figure 165 illustrates the square press which with the exception of the square plates "A" and the flap cocks "B" is the same as the round press construction.

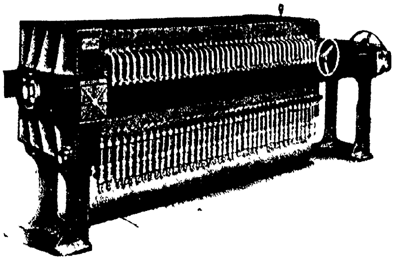


Fig 165
Square Plate and Frame Filter

The presses may be of the center feed or corner feed type, the former being the most common. Figures 166 and 167 show round and square plates with center feed and outlet cocks. The

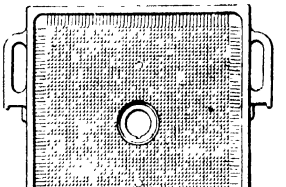


Fig. 166
Square Plate

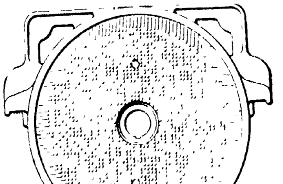


Fig 167
Round Plate

surface of the plates in both cases is the pyramid design which gives a maximum area of filtering surface for the cloth The recessed plate shown in Figure 168, has a corner feed and radiating ribbed surface. The outlet cock has a curved nipple so that the filtrate may be switched from one trough to another as required.

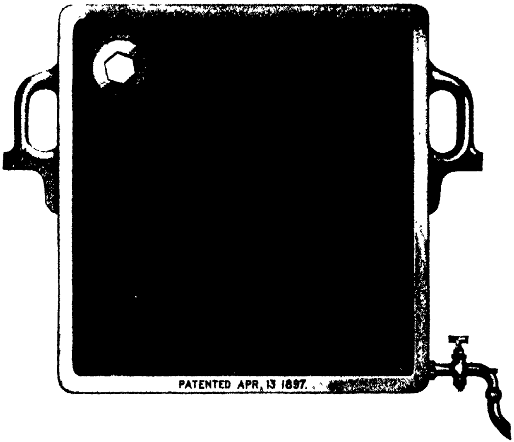


Fig. 168
Plate

In operation a plate filter press is fitted with cloths, closed up and locked. The feed pump is started and the slurry passes through the feed openings in the various plates. The solids are left in the chambers where they build up in a solid layer or cake, while the filtrate passes through the cloths and out through the filtrate cocks. At first the pressure is low as there is little resistance offered by the cloths, but as the cake builds up the pressure increases, due to the necessity of forcing the liquid through the cake. When filtration is finished, usually, as determined by the high pressure shown on the gauge and the low rate of flow at the outlet cocks, the pump is stopped, the press unlocked, opened, and the cake removed from each chamber. This removing of the cake is done by hand and the cake itself is dumped onto a tray or some conveyor if it is to be saved, otherwise it is generally washed to the drain. When the cake has been all scraped out and the joint surfaces are clean the cloths, if they do not need washing, are replaced and the press closed up for another run.

If a recessed plate press is used for washing, a channel is formed in the lug at one side of the press and water admitted behind the cloths. The wash water passes through the cloths, then the cake and discharges from every alternate cock, the remaining cocks being closed. The recessed plate press is seldom thus used as a washing press as other types are more efficient. Its general use therefore is where washing is not required and where the slurry to be handled is so thick as to clog low pressure filters. It has only half as many joint surfaces to keep tight as the plate and frame type, weighs less, and is cheaper to install. It has the disadvantage as compared with the plate and frame press, however, in that there is a much higher consumption of cloths because of the stretching due to the recess on the plates. Cakes should not built over one and one-quarter inches thick on recessed plates alone.

Plate and frame presses may be divided into classes according to the method of feeding. In the internal feed press, eyes are cast in the plates and frames inside of the joint surfaces. When the plates and frames are pressed together these eyes form a continuous channel. This channel forms a passage for the material to be filtered, and connects to the interior of the frames by cored inlet ports. The external feed press has external lugs which form the channels for feeding and washing. These lugs are

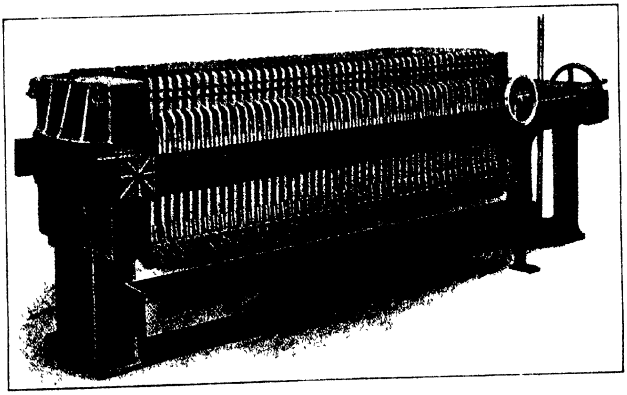


Fig. 169
Plate and Frame Filter

made tight by means of rubber collars. A type of square, corner feed, two-eyed, open delivery, washing, flush plate and frame filter press is shown in Figure 169. In this type an eye or hole in one corner of the plates and frames forms a channel for the introduction of slurry to be filtered, the other hole is for wash water. In Figures 170 and 171, may be seen a three-eyed and

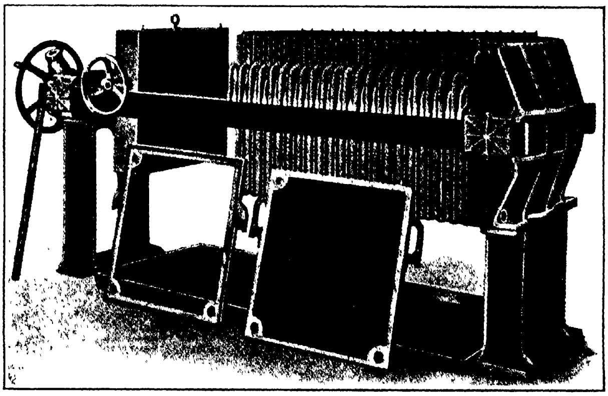


Fig. 170
Plate and Frame Filter

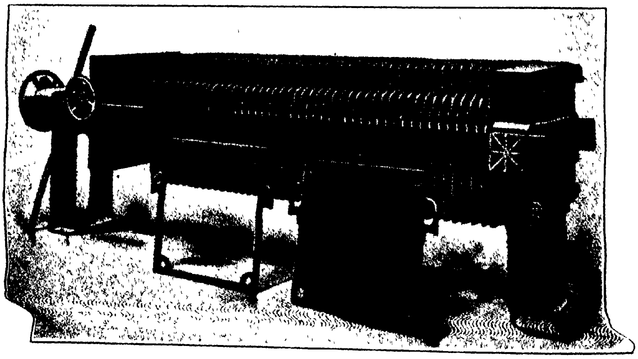


Fig. 171
Plate and Frame Filter

four-eyed press. The plates and frames are shown standing by the filter and the eyes can be plainly seen.

One of the types of flush plate and frame presses which has been adopted by many users is the square, outside feed, open delivery, washing filter shown in Figures 172 and 173. In Figure 174 is shown a ribbed plate which is often used in this type of press. The side feed plate and frame press is one of the most improved plate and frame press on the market. The sludge is fed into the chambers through a channel at the side of the press formed by holes in the plates and frames. This channel is made tight by rubber collars inserted in the holes of each plate and frame. The design makes it unnecessary to cut

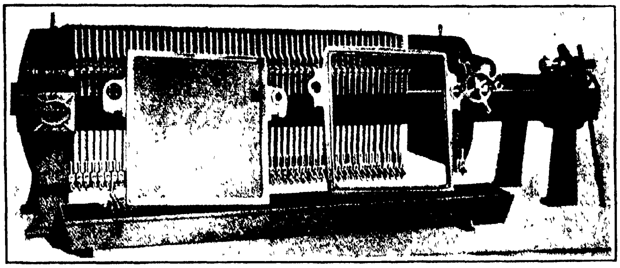


Fig. 172
Plate and Frame Filter

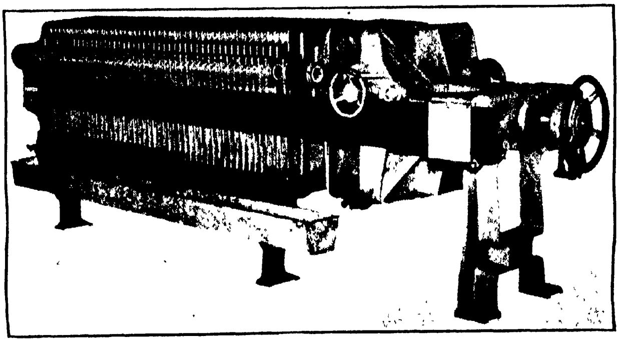


Fig. 173
Plate and Frame Filter

holes in the cloths and the clothing of the filter press is a simple operation. It is only necessary to cut the cloths to the proper lengths and fold them over each plate. In washing, the liquid is pumped through a channel in the side of the press opposite the feed channel, and similarily provided with rubber collars.

For filtering solutions that have to be handled at high or low temperatures plate and frame presses are made of plates having hollow centers. A channel formed by eyes running the entire length of the press connects in multiple all hollow interiors. Steam or brine solution may be circulated to get the desired temperature.

Figure 175 illustrates the triangular plate and frame press with the discharge cocks at the top. This type is one of the few filter presses used on ore slimes in this country. It is employed in conjunction with aluminum dust for the precipitation of silver and powdered charcoal for the precipitation of gold. The presses are triangular in section and the feed pipes are so arranged that the solution and precipitant enter from the bottom or apex of each container. In this way the solids gradually accumulating in the frames are kept constantly agitated. These filter presses provide a uniform filtering layer of fine grained precipitant through which every particle of solution must pass, insure the necessary con-

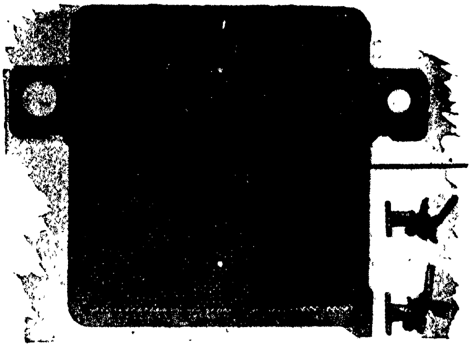


Fig. 174
Plate

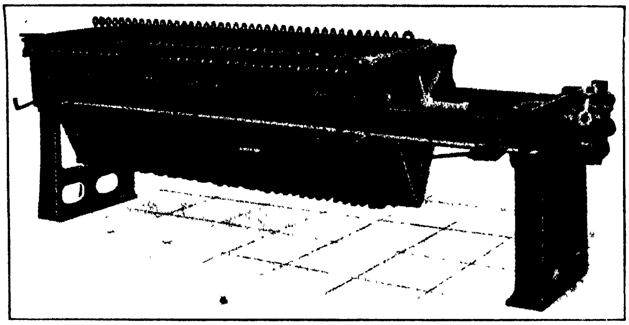


Fig. 175
Triangular Plate and Frame Press

tact between each metal bearing molecule and the precipitant and also completely separate the precipitated metal and the unconsumed precipitate from the barren solution.

Figure 176 shows a frame with the slurry inlet at the top connecting with a distributing pipe to the apex. Figure 177

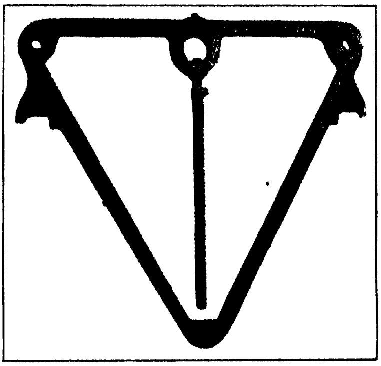


Fig. 176
Triangular Filter Frame

shows the plate with the filtrate outlet on top, and a discharge outlet on the bottom for flushing out the chamber.

Where sparkling clear filtrate or where a second filtration is required the Perrin Wood Pulp Filter, made in France, is very

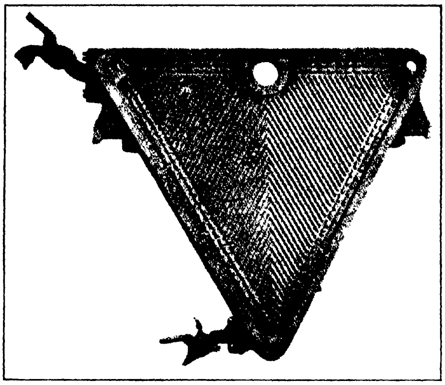


Fig. 177
Triangular Filter Plate

often used. This filter is not designed to handle large amounts of cake but for the uses above mentioned it has found success in Europe, the Far East and in the United States.

The filter is made of cast iron and steel or any metal that may be required, according to the solution to be filtered. An illustration of one of these filters in a sugar refinery is shown in Figure 178 and a cross section is shown in Figure 179.

By referring to Figure 179, the parts of the press and its operation may be seen. It is composed of iron frames "P_1," "P_2," etc., which are circular in shape. Upon these frames is placed a perforated metal screen "d" and upon the screen the paper pulp "e" leaving spaces "c" between the frames. The entrance for sludge is shown in the center of the press at "a," and "b" is a metal ring inserted between the frames for double filtration. There are openings in the frames for passing juice or liquid from one frame to the other for such filtration. The filtrate outlets from each frame are shown at "R_1," "R_2," etc. The inlet valve is shown at "V" and the wash inlet valve is shown at "v_1." A trough for collecting the filtrate is shown at "N." The ring "y" at the top of the press is used to facilitate the removal of the cover by a chain block, as shown in Figure 178.

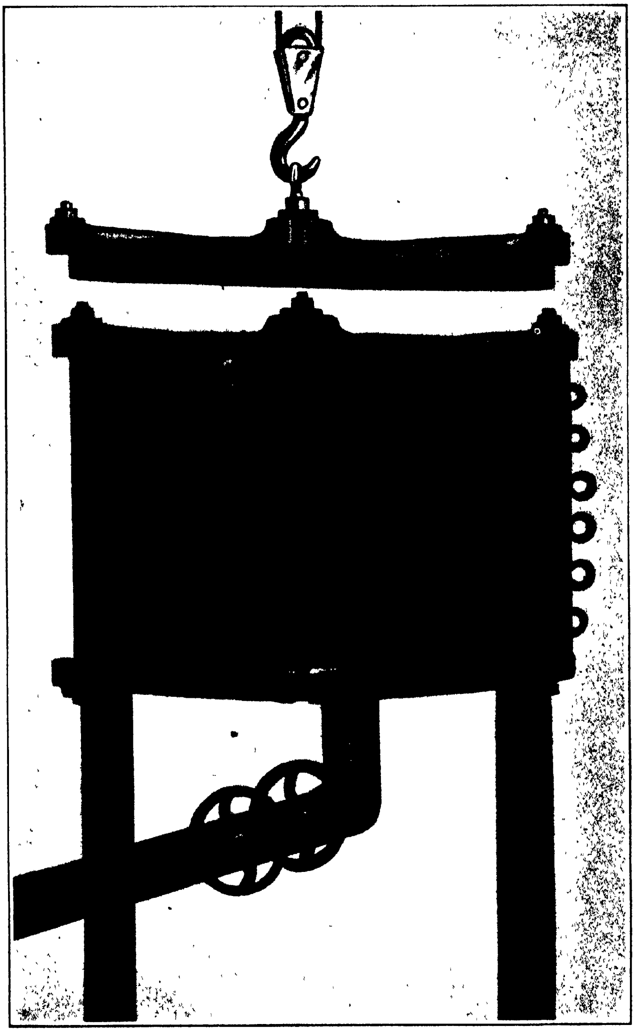


Fig. 178
Perrin Filter

A cycle of operation of this filter is as follows: The paper pulp is disintegrated and placed upon the perforated bottoms of the frames and tamped down evenly and lightly over each frame. The frames are placed in the press one by one and the cover put on. The pump is started, valve "V" is opened and the sludge enters through the central inlet "a" and into the frames. The clear liquor passes through the filter bed of paper pulp into the space "c" below the screen and out of the filter cocks "R_1," "R_2," etc. In case a double filtration is desired a frame with a hole in it at "t" and a ring "b" between the frames is required. The ring "b" prohibits the sludge from passing into the corresponding inlet to the frames and the filtrate passes through two beds and out of outlet cock "R_1," as "R_2," is closed.

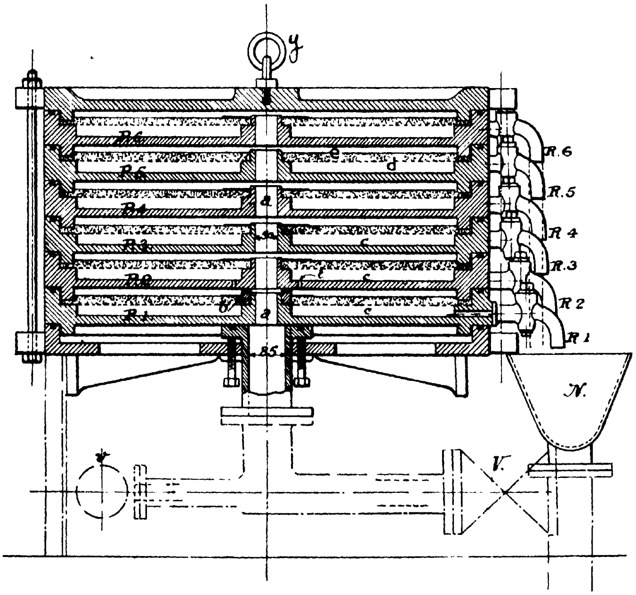


Fig 170
Perrin Filter—(Section)

Washing is accomplished by admitting wash water through valve "v," after valve "V" is closed. The wash water follows the same course as the sludge and filtrate. When the paper pulp becomes too dirty for economical filtration, the filter is taken apart, the paper pulp taken out, washed in a special washing machine and returned to the filter.

This filter has the advantage of using the filtering medium over and over again so that it eliminates the expense of filter cloths, as paper pulp is coated directly on the perforated screen. The filter is very cheap to operate and maintenance is low.

The disadvantages are that they are slow filtering compared with some other types and they must be taken apart to clean. A special washing machine must be employed for washing the pulp clean and the pulp must be leveled and tamped on the frames by hand.

Filtration and clarification of acid solutions or materials influenced by contact with iron or other metals is frequently required. In such cases plate and frame presses made of wood are practically the only kind which can be used satisfactorily. These presses are so constructed that the solution being filtered does not come in contact with anything but wood or acid resisting material. The plates and frames are usually of selected yellow pine, but may be constructed of cypress, maple, oak, etc., or such wood as may be required for special work. All channels through the head are lined with brass, bronze, lead, aluminum, fibre, hard rubber, etc., depending upon the material to be filtered. The head and follower are protected by specially constructed liner

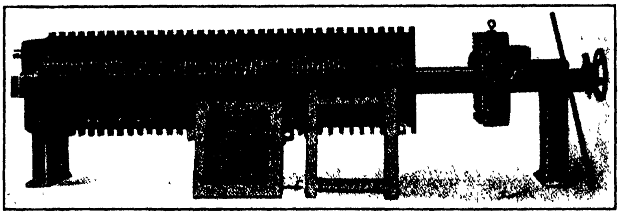


Fig. 180
Wooden Plate and Frame Filter

plates. The press frame is similar to the standard cast iron press frame as made by the different manufacturers. A view of a typical wooden plate and frame press is shown in Figure 180. The construction of wooden plates and frames with a movable field and rigid outer frame on the plate is shown in Figure 181. This moving field tends to prevent cracking of the wood as contracting and expanding with variations of moisture is equalized. These plates and frames, form presses that need no outlet cocks, the filtrate passing through a closed channel and out of the head of the press thereby giving a closed delivery.

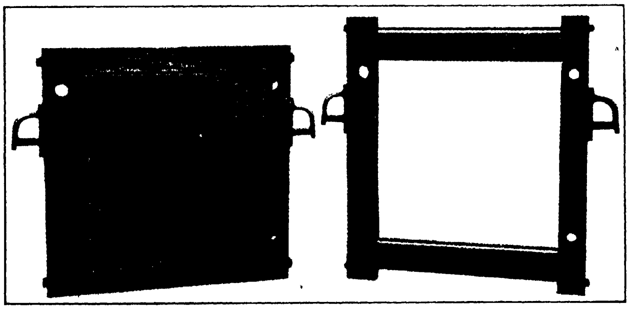


Fig. 181
Wooden Plate and Frame

The operation of a recessed plate press and that of a plate and frame press is divided into five steps briefly mentioned on Page 210. They may be classed as follows (a) clothing or putting the cloths on the plates, (b) closing or squeezing the plates together, (c) filling or pumping the material into the press, (d) washing, (e) opening or emptying the contents of the press and scraping the cloths. The first step or clothing of the press is done by throwing a sheet of cloth over each plate. If the press is inside feed, holes are cut in the cloths so that they register with the holes in the plates. If the feed is outside, no holes are needed., Clips or lugs are used to fasten the cloths around the holes unless sewing is resorted to. In step (b) all the plates and frames are placed together in the press, care being taken to see that the cloths lie smooth in the joints. The slide-head is then brought up against the plates and pressure applied according to the type of closing device used. In (c) the filtrate cocks, if open delivery press is used, are opened, and the material to be filtered is pumped into the feed inlet. The filtrate will issue from the filtrate cocks, or if a closed delivery press is being used, it will issue from the outlet in the fixed head. When the filtrate nearly ceases to flow, or at the expiration of any other predetermined length of time, the press cake is ready to wash or to be dumped if washing is not required. If the filter is a washing press wash water or whatever solution is used for washing is pumped into the press, step (d). Washing may be done in two ways, as may be seen by referring to Figures 182, 183 and 184, which are cross sections. The recessed plate, as shown in Figure 182, and the flush plate and frame, Figures 183 and 184. In Figures 182 and 183, the wash water is pumped in through the feed channel and washing must be done before the cakes grow together on the cloths. This is not very effective as the operator cannot always tell when to stop filling as the cakes vary in building up during each run and in different parts of the press. In Figure 184 there are two channels, usually in opposite upper corners. One is the feed channel and the other the washing channel. This latter channel runs the full length of the press and drops into every other plate. In washing the connection to the feed channel is shut off as are also the cocks, if open delivery is being used, on those plates into which the wash water channel enters. When the wash water is turned on it fills the space behind the cloths in every other plate and in order to get out must pass through the cake up against

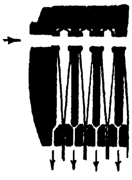


Fig. 182

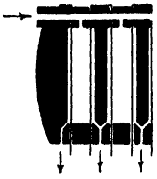


Fig. 183

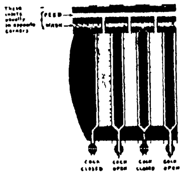


Fig. 184

Fig. 182—Cross Section—Recessed Plate Press
Figs. 183 and 184—Cross Sections Flush Plate and Frame Press

the opposite plate and out through the open cock. In the case of closed delivery presses where no cocks are used there are two channels, each of which drops into an alternate plate. When filtering, these two channels are connected parallel outside of the press, but when washing, one channel is cut off, the other draining the water from every other plate. It often happens that there is not enough material to fill up a press and a dummy plate, Figure 185, is used. This dummy may be inserted at any point in the press and the desired number of chambers eliminated.

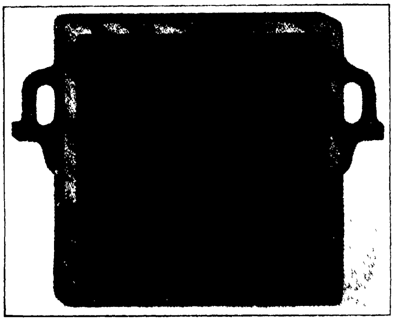


Fig. 185
Dummy Plate

Different closing devices may be used on filters of this type and different degrees of closing pressure thus obtained. Hydraulic pressure is sometimes used particularly in large presses,

Fig. 186
Hydraulic Plate and Frame Press

Figure 186. Floor pans are used under presses to catch drippings etc., and these pans are often provided with outlet holes for connection to piping.

Various kinds of cocks are used as filtrate outlets and troughs or gutters to carry off the filtrate. The switch cock as shown, Figure 187, is to cause cloudy liquor to flow back for refiltering and at the same time provide for clean liquor when it appears.

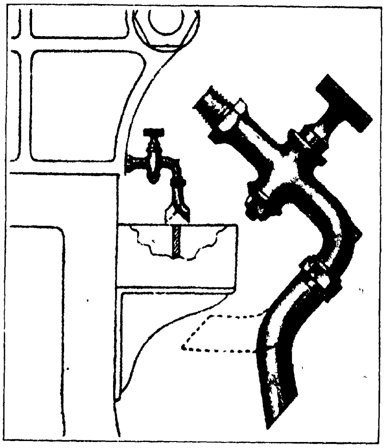


Fig. 187
Switch Cock

The claims made for filter presses are: (a) greatest amount of filter area per unit of floor space, (b) lowest cost per square foot of filter area, (c) low cost of repairs, (d) does not require skilled labor, (e) produces a solid dry cake which is easily handled, (f) high pressures can be employed.

Some of the disadvantages are that a great deal of filter cloth is consumed since the cloths act as gaskets between the plates and frames and the tighter the press is closed the harder it is on the cloths. A little roughness or worn cloth on the edges cause leaks. A good deal of labor is required when compared to newer types of filters and the cloths cannot be automatically cleaned but must be scraped by hand. As the cake is built up by increasing pressure it is not uniform in density and therefore is difficult to wash efficiently. Finally in discharging the cake by opening the press there is usually some slurry or wet cake which falls out and not only is a waste of material but makes it very difficult to keep the place around the press clean.

Since there is such a similarity between the presses of different makes no attempt has been made to point out the distinguishing features of each make. Practically all manufacturers make round and square presses, center or side feed, one-, two- or three-eyed, recessed and plate and frame, wood or iron, and hand or hydraulically closed presses. The construction of the plates themselves differ somewhat as in grooved or ribbed surface, which may be broken lines or continuous, etc. Among the prominent filter press manufacturers are the Allbright-Nell Company, Carbondale Machinery Company, Ernest H. Du Vivier, Independent Filter Press Company, John Johnson Company, Love Brothers, Merrill Filter Company, T. Shriver and Company, D. R. Sperry and Company, United Filters Corporation and Wm. R. Perrin and Co.

CHAPTER XI

LEAF FILTERS

As was mentioned in Chapter II leaf filters with the possible exception of the Danek and the Philippe were conceived to handle slurries which required the greatest care and economy in removing the mother liquor from the cake, where it was held as the moisture content. The special idea in design was that a cake should be produced which was uniform in thickness and porosity and that the actual cost of operation be reduced to a minimum. In order to do this the cakes built up were not allowed to touch, as this would make washing uneven and discharge difficult, especially as the pressure through the interior of the leaves was intended to cleanse the filter medium automatically as well as discharge the filter cake, and thus keep down operation costs. The filters produced are operated under pressure or vacuum or both, according to the make. They cut down labor and operating expense in many plants and in numerous installations justified their claims by making feasible extractions which had hitherto been impossible. The filters of the leaf type in most general use to-day are the Buflovak, Burt, Danek, Philippe, Hendryx, Kelly, Sweetland, Vallez and the Zenith (Moore).

Buflovak Vertical Filter.—The Buflovak Vertical Filter shown in Figures 188 and 189 employes as a filtering medium, bone black or other materials and it is used mainly for sugar filtration. The filtering medium is inserted between two concentric screens contained in the filter. The inner screen and the top on the filtering material are covered with filter cloth. The filtration takes place through the outer screen through the filtering medium into the inner screen and out. Provision is made against floating of the material and the formation of short circuiting channels. When the filtration is completed, the filter is drained, and the impurities are removed by blowing with steam through the filtering mediums in the opposite direction, this cycle being repeated until necessary to renew the filtering materials.

The machine will give good results as it does not need to be opened for discharge but is not especially valuable if the medium clogs quickly or has to be renewed frequently.

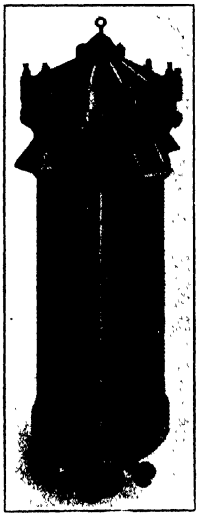


Fig. 188
Buflovak Filter (Section)

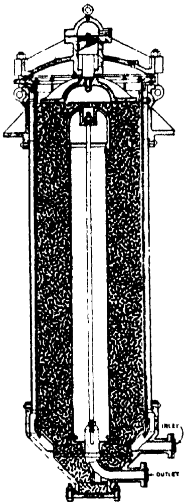


Fig. 189
Buflovak Filter

Burt Filters—The two types of Burt Filters, the Burt Rapid Cyanide Filter and the Burt Revolving Filter are made by Chalmers and Williams. These machines are primarily slimes filters and as such were designed, developed, and are largely employed for gold and silver ores treated by the cyanide process.

The Burt Rapid Cyanide Filter is especially adapted for handling slow settling slimes which usually contain a considerable percentage of amorphous matter. It operates under a pressure of from 25 to 40 pounds, depending upon local conditions and the character of the slimes to be handled, and has a capacity likewise dependent upon the character of the slimes, local conditions, method of operation, the operator, etc. The filter consists of a steel plate cylinder at an angle of about 45° to the horizontal. The filter plates or mats are suspended inside from the top of the shell so that the filter is practically self-contained. Figures 190 and 191, respectively, show an end elevation and a side elevation of the machine, with part of the shell broken away so

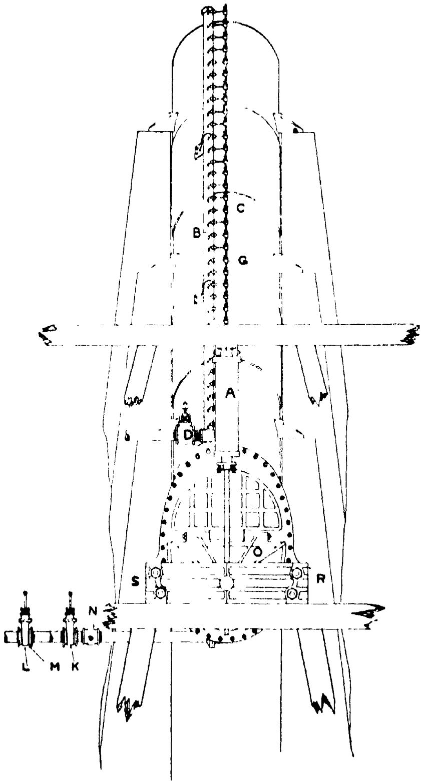


Fig. 190
Burt Filter – End Elevation

as to illustrate the filter mats inside. The door "O" is held in position, when there is pressure inside the cylinder, by means of the toggles "Q," which are moved by the hydraulic cylinder "A." The cross-head "R," against which one of the toggles bears, is held in position by four bolts "S." The leader pipe "N" has three quick opening gate valves, "L," "M" and "K," for connection to the slime supply, the excess slimes discharge and the wash water respectively. Each filter mat is made up of a bent pipe which forms the frame, a piece of cocoa-matting which fills the space inclosed by the pipe and two thicknesses of canvas

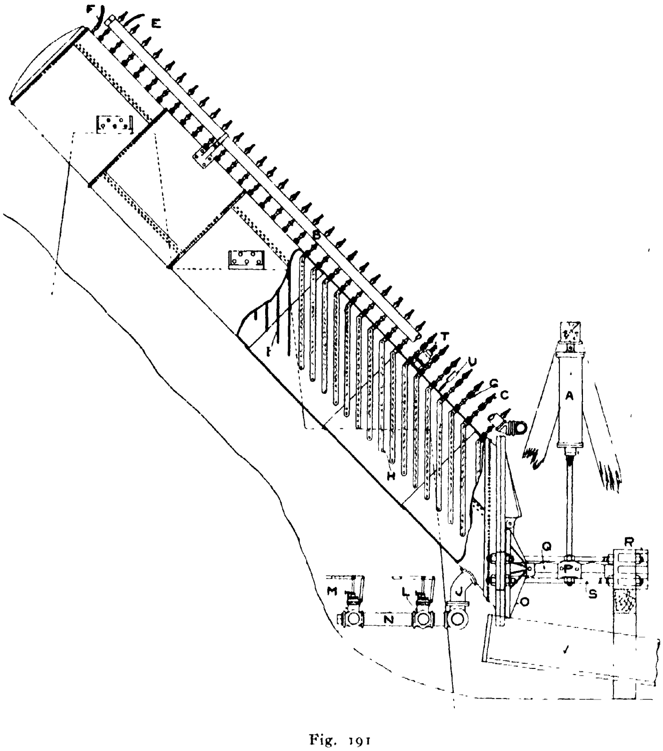


Fig. 191
Burt Filter—Side Elevation

one on each side. These pieces of canvas overlap the pipe, and are sewed as well as securely stitched through and through the cocoa-matting. The pipe is perforated with small holes around its inner side and is carried by a special tee which permits it to swing slightly from a vertical position. There is a cock "G" in the connection with the solution discharge "B," also a tee that is fitted with a cock "C." By means of the cock "G," a filter mat may be cut out without interfering with the operation of the balance of the mats. There is a connection for compressed air "E" to the discharge pipe "B," and another connection for compressed air "F" to the inside of the shell.

In operation the slime is forced in under pressure until a cake "H" of the desired thickness is formed on the mats. Then the slime valve is closed and the air valve "F" and the discharge valve "M" are opened. Air is admitted to the shell and forces out all of the excess slime at the same time holding the cake in place. The valve "M" must be so regulated as to maintain a pressure of from 5 to 10 pounds. The excess slimes are returned to the supply tank. The discharge valve is then closed, wash solution or water admitted and the air valve closed. When the cakes have been washed a sufficient length of time the excess liquor is removed in the same manner as the excess slime. The time required for washing must be determined for each particular case by trial. After the excess wash liquor has been removed, air pressure may be raised and the cakes air dried. The air valve "F" and the solution valve "D" are then closed, the door "O" opened, by means of the hydraulic cylinder, air at a low pressure admitted to the pipe "B," and through its connections to the filter mat pipes, thus causing the cakes to drop off and slide out of the shell. In dislodging the cake air is more effective if given in puffs than in a continued flow. The condition of the filter mats can be told by closing the cocks in the branch pipe connecting to the solution pipe and opening the cock "C" on top of the tee. The cylinder which controls the door can be operated by compressed air or hydraulic power.

The filter may be placed in nearly a horizontal position, having one end about 6 inches lower than the other, if solutions are to be handled. There is a pipe connection at the lower end for pumping in the solution and another for a blow-out pipe. The filtered solution runs from the filter mat connections into a launder which conducts it to the precipitation room. To clean off the mats an air nozzle is held for a second or two to each connection to the filter mats, causing the slime to fall into the bottom of the shell. To assist in cleaning the cloths holes are arranged along opposite sides of the shell, closed with plugs. Through these openings a small stream of water, under high pressure can be directed against the cloths.

The Rapid Cyanide Filters are built in large sizes 20 or more feet long and 4½ or more feet in diameter so that they are expensive to install. Their process is intermittent and requires labor, while difficulty is often encountered in obtaining a clean discharge. The use of cocoa-matting, while it gives a very porous gathering-space for the solutions and also sufficient support to the canvas, is costly and clogs, so much so that it has been abandoned in the Butters and other types which used it. The filter has only a limited use and as good agitation is impossible an uneven cake is likely to be formed which can not be washed efficiently. It is claimed for this machine that it has a lower initial cost per square foot of filter area than other accessible filters of the cylindrical shell, movable unit and leaf type while the operating cost is no more. It occupies less space and gives a drier cake than the suction leaf filters and does not cost much more for operation.

The Burt Revolving Filter is not a continuous rotary filter but a leaf filter in which the leaves are shaped to the container and revolve with it. The machine is designed for handling granular slimes, a mixture of fine sand and slime or similar material, which will settle quickly and form a cake readily. The filter operates under a pressure of from 35 to 40 pounds. The feed end is supported on a trunnion bearing and the discharge end is supported a short distance from the end on a roller bearing.

The shell is made in three sections, the maximum length of a section being 20 feet. The slimes and washing liquid are charged through the hollow feed end trunnion and the cake is discharged at the opposite end. The discharge end is closed by a cast iron door operated by means of a hydraulic cylinder and system of levers. The filter mats are fastened to the inner surface of the shell by means of specially shaped angles and bolts. During formation of the cake the filtered solution is discharged, as shown in Figure 192, on to a floor from which it is conveyed to receiving sump.

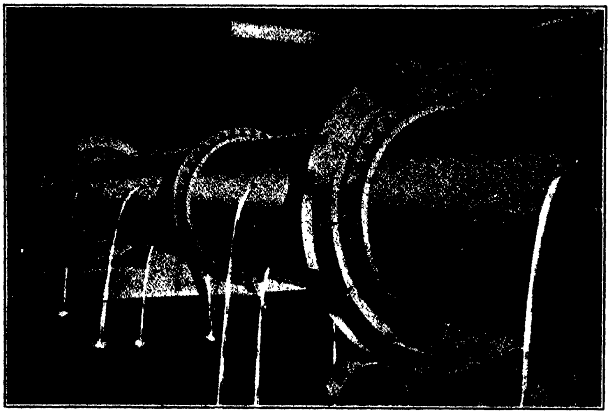


Fig. 192
Burt Filter

The cone-shaped casting to which one end of the toggle arms are fastened is held in position relatively to the end of the filter shell by means of heavy rods or bolts. On these rods are springs which aid in closing the discharge door. The door is positive in its action and opened and closed by means of a piston, operated in a cylinder, as shown on Figure 193, by hydraulic pressure. At six intermediate points on the door, situated between the rods on which it slides, are fastened one end of the toggle joint, the other end being fastened to the cone-shaped cross-head One end of each toggle extends an arm at right angles to its length to the center piston rod.

On the piston rod is located a large iron collar. When the springs push the door shut, the ends of the six levers converge towards the piston rod, their ends being in the path of travel of the collar, and as the piston rod is allowed to slide through the door a few inches after it is shut, the collar comes in contact with the ends of the levers, pushing them forward, thus straightening out the toggles and exerting a tremendous pressure at six different points on the door. This is a simple, powerful device

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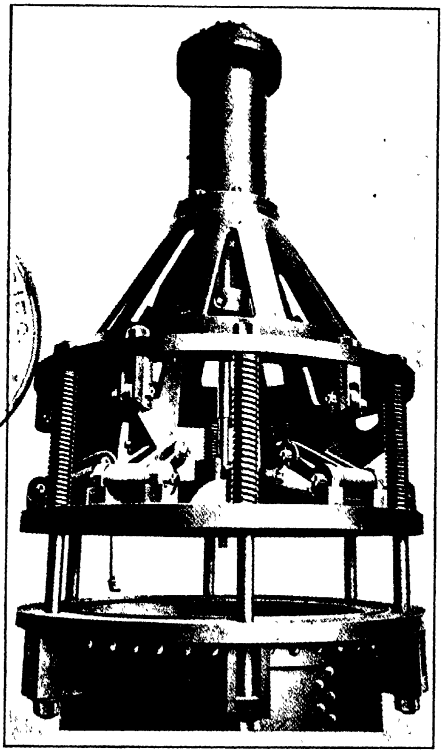


Fig. 193
Burt Locking Mechanism

and is very easily adjusted by moving the collar on the piston rod either forward or backward on the threaded part of same. The joint between the door and the flange on the cylinder is made by means of a square rubber gasket Figure 193 shows the door open.

The filter cloths are made about 28 inches wide by 10 feet long, there being five cloths in the circle. These cloths are interchangeable and are held in place by angle irons which are slipped over studs fastened in the shell at the point where two cloths meet, thus extending over half of one cloth on one side and over half of the cloth next to it on the other side. Each cloth has its individual outlet at the center for the filtered solution.

The filter is revolved continuously at about fifteen revolutions per minute. The discharge door being closed, the slime feed valve is opened until a proper charge has been admitted to the filter; the slime valve is now closed and the air valve opened and pressure at 25 to 45 pounds maintained until all of the solids are formed into cake, which is signified by the filter blowing air. The air valve is now shut and if the wash solution is under sufficient head to overcome the pressure in the filter it is allowed to enter at once; but if there is very little head, the escape valve of the filter is opened and the pressure dropped enough so that the wash solution will enter. The required amount of wash solution is run in, then the valve is closed and more air admitted to force the wash through the cake. When the filter starts blowing, wash water is admitted in the same manner as the wash solution and when finished the pressure is dropped to zero and the door opened.

It is only necessary to add enough water to make the canvas slippery so that when the falling cake forms into a round loaf, the cylinder will be sliding under it and this action causes the cake to move towards the discharge door. The water is added in a small amount at one time just as the cake falls.

The filter has the primary advantage that a uniform cake is built up, by the revolving of the cylinder, and therefore a very excellent washing with a small amount of water can be obtained. The filter opens wide enough for admission of a man for inspection and the leaves can be readily removed. A small amount of water is needed for discharge; power consumption is low as everything that goes into the filter comes out through the filter leaves and the shell except the solid slime cake.

The fact that a dry cake cannot be discharged makes it possible only to use the filter where this is of no consequence. The machines are expensive and take up a good deal of room, an ordinary size is one 42 inches in diameter by 40 feet long. They are intermittent and so the cost of operation is high.

Danek Filter.—The Danek Filter was designed to clarify sugar juices after carbonization and it is within this field almost entirely that the filter is used. It found much more favor in Europe than in this country, despite the competition with the Philippe filter. The Danek is sometimes considered to be the first real leaf filter consisting as the leaves do of a rigid frame behind the medium instead of simple bags as in the Taylor filter. The leaves are hung in a closed container discharging at the top into a common gutter on the outside, so that pressure can be used to force the juices through the filtering medium. They have the advantage over the Taylor filter bags in that they are more easy to clean, but the disadvantage in that they are more difficult to disconnect and more expensive to install. Inasmuch as the Danek is very little used in this country and reliable information concerning it is hard to obtain, this type will not be taken up in any further detail.

Philippe Filter.—Like the Danek Filter the Philippe, which is manufactured by the Societe Philippe, was brought forth to clarify sugar juices and the leaves consist of a rigid frame behind the filtering medium. It is operated by gravity and is cheap to install and maintain although the washing of the cloths is a great handicap and labor consuming feature. There are still many Philippe Filters in sugar refineries both here and abroad and a few of these filters in other industrial plants.

In Figure 194 "A" represents a metal vat surrounded by a fixed grating "B" made of cast iron and permanently fixed to the vat. Through the grate openings the filter frame "E," covered with a cloth bag "D," is inserted and extends into the solution to be filtered. The frame "E" is of steeel or other metal wire mesh as required, with a pipe around the edge to form the frame. This frame is inserted in a bag the open edges of which are held tightly together against the bars "B" by the hollow caps "G," and screwed down by tightening the bolt "H," covering two of the caps at a time. These hollow caps also serve as an outlet for the filtrate which then passes out through a nipple "I" to trough "K." The sludge to be filtered enters through the pipe and valve "L" while the pipe and valve on the bottom at "M" serve to empty the tank of mud which accumulates there.

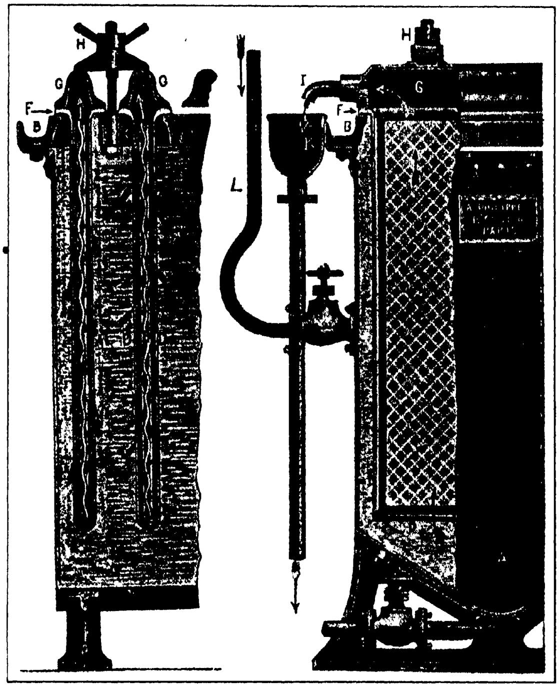


Fig. 104
Philippe Filter (Section)

In operation all valves are closed with the exception of the inlet. The filtrate drains out by gravity and no attention is required until the rate of flow almost ceases, when the inlet valve is closed, the filter drained of excess sludge, and wash water admitted. After the effluent shows that the washing is complete the filter is again drained and then opened. The leaves or the cloths alone are taken out and washed. New cloths may be put on at once so that operation can continue without having to wait for the first cloths to be cleaned.

The filter (Figure 195), as before stated, is principally used in sugar refineries or where a gravity filter is required for clarification or for separating out light fluffy solids. It has the advantage of a large filtering surface enclosed in a small space, smaller than the Taylor, with each bag individually controlled, and provision for the shrinkage of the bags over the frames but the slow process of filtration by gravity makes large areas necessary

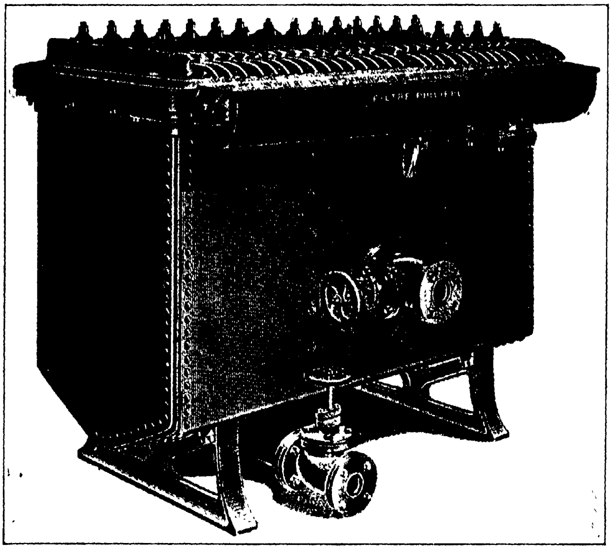


Fig. 195
Phillippe Filter

and the cleaning of the cloths and the removing them from the frames consumes a good deal of labor.

Hendrix Combination Agitator and Filter.— The Hendrix Cyanide Machinery Company makes an agitator for the rapid extraction of metals from sands and slimes by means of agitation and aeration in solutions, as described in Chapter XVI, and to this agitator is often added a leaf filter.

The Hendrix Combination Agitator and Filter is designed to cheaply dissolve the gold and silver and separate the value-bearing solution from the tailings, in one operation.

The apparatus, as illustrated in Figure 195 (a), differs from the plain agitator only in having filter cells. The filter cells are located vertically beneath the distributing and aerating apron and consist of a wooden frame with iron tees and elbows. A piece of cocoa matting on wood strips is placed in the inside of the frame. The entire frame is enveloped in canvas—and the canvas and cocoa matting are quilted together at intervals.

In operation the filtered solution flows by gravity from a tee at a lower corner of the frame, while a tee at an upper corner serves the purpose of introducing air or wash solution to clean the cell. By the use of rapid agitation and heat, the slime is coagulated so that it settles rapidly. Vacuum or pressure is not used on the filter cells, the solution filtering off by gravity alone.

As high as a ton of clear solution per minute has been obtained from an eighteen-foot machine, the apparatus containing approximately 6,000 square feet of filtering surface. The time necessary to complete the filtration and washing of a charge ranges from two to four hours, depending upon the character of the ore.

These machines are made in sizes to handle from 200 pounds to 100 tons to the charge.

The gravity filter cells will not successfully handle all and every known material but will filter most materials that vacuum and pressure filters can handlle. They have the advantage of excellent agitation and consequently a uniform cake is built up. Gravity, however, gives a low rate of flow, washing is cumbersome as it means the emptying of the tank of sludge and refilling with water, and the filter medium clogs easily and is rather expensive to replace.

Kelly Filter.—The Kelly Filter is manufactured by the United Filters Corporation. This machine, which uses pressure for filtering and requires drawing out of the leaves from the shell for discharge, enables very large capacities to be handled in a relatively small machine. Like many other leaf filters it was first developed in the mining field as a modification of the Moore type and has since been applied to other industries.

The principle parts of the Kelly Filter are shown in Figure 196 and consist of the supporting frame "A," the pressure tank or press shell "B," the filter carriage "C," the filter leaves "D," and the quick locking head mechanism "E." The pressure tank or shell is made of steel, with the front end open, with a heavy cast iron ring riveted around the edge, and the rear head dished. "U" bolts pass through lugs in the periphery of the ring engaging the radial arms of the head locker. On the underside of the ring on the center line is a boss, faced and flanged for a pipe inlet. The ring also has an annular groove in which a gasket is placed. In this groove fits the angular tongue on the inside of the cast iron head of the press. The filter carriage, which holds the leaves, consists of supporting plates at each end fastened together with channels. The cast iron head of the filter press forms the front end of the carriage. This head is mounted on wheels which run on outer tracks on top of the "I" beams. The rear end of the carriage is mounted on wheels which travel on rails supported on brackets inside of the press shell. The carriage passes into the press shell, the front head closing the front end of the shell. The filter leaves are rectangular in shape running longitudinally in the press shell. They are of the same length but of varying widths, and are made of rolled steel pipe and double crimped wire screen. The forward corners are connected to the head of the press by nipples and unions. All filtrate passes through these openings, through the head and out of the press. The leaves are covered by cloth made in the form of a bag and after the bag is drawn over the frame the open

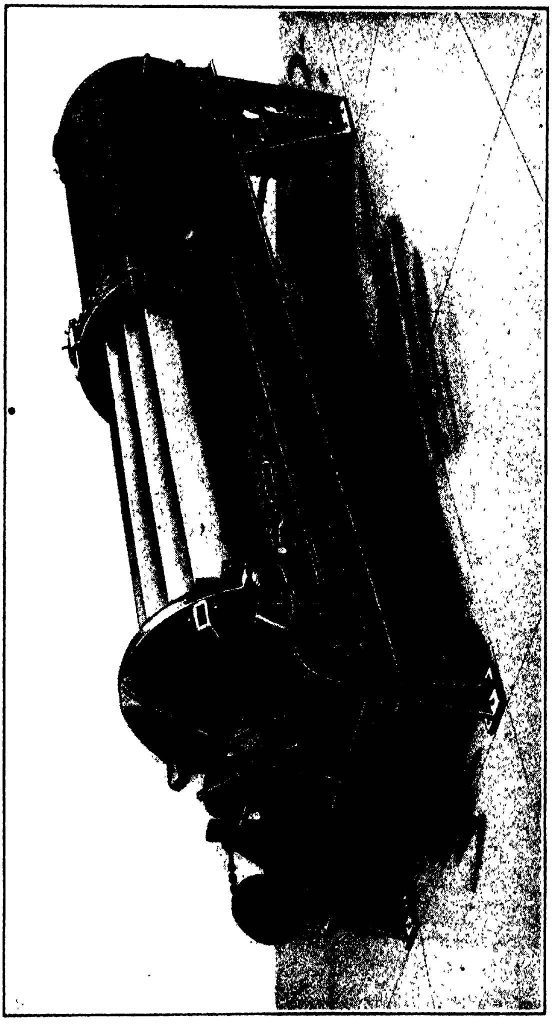


Fig. 196
Kelly Filter

edges are sewed up by hand. Formerly these leaves had wooden spacers sewed in them as in the Moore type. The head-locking mechanism consists of radial arms, the inner ends pivoted to a movable collar propelled along a central shaft by a toggle. This toggle may be operated by a hand lever, a hand wheel, or when power is used to operate large presses the process is self-locking.

A cycle of operation is divided into practically three distinct steps, *viz.*; building cake, washing cake, and discharging cake. By referring to Figure 197 and following the operation as given, the cycle can be readily followed.

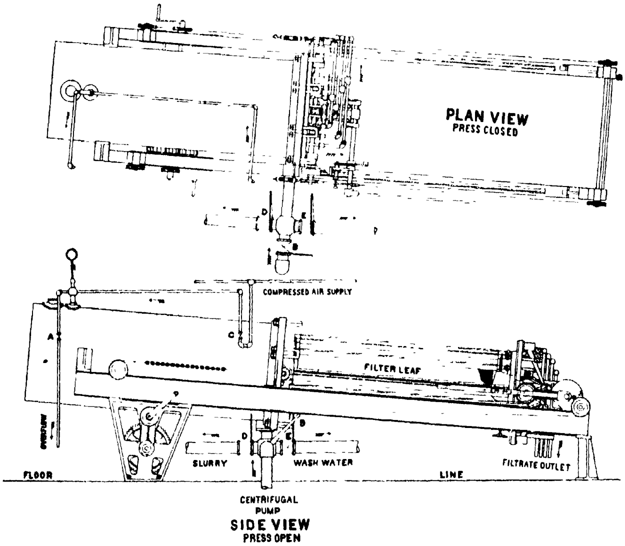


Fig. 197
Kelly Filter

(a) 1. Close and lock press.
  2. Open valve "A" on overflow line.
  3. Get sludge in supply line to press.
    (a) If using pump—start pump.
    (b) If using pressure tank—turn on pressure.

4. Open inlet valve "B" to press.

5. When sludge appears at overflow close overflow valve "A."

6. Continue forcing sludge into press until proper thickness of cake is obtained. (Note) To determine the time necessary for building the proper thickness of cake on any particular material, filter consecutively say 2-4-6 minutes, etc. When once determined, this time is always used.

Do not permit the cakes to build together, as the washing will not be complete and the filter leaves will warp.

7. Close inlet valve "B" to press, turn on compressed air at "C," not to exceed 10 pounds, open excess sludge valve "D" and empty press of excess sludge back to supply tank.

8. If cake is to be washed, get wash water in supply line while emptying press of excess sludge.

9. When press is empty of excess sludge which is indicated by sudden drop in air pressure, close excess sludge valve "D" immediately, when pressure starts to drop.

Note.—If cake is not to be washed proceed from here to No. 14.

(b) 10. Open inlet valve "B" to press, shut off air pressure at "C" and hold 5 to 10 pounds pressure in press by means of releasing through overflow valve "A."

11. When water appears at overflow, close overflow valve "A" and continue washing at same pressure as used in building cake, until desired results are obtained.

12. When finished washing, shut inlet valve "B" to press, turn on air at "C" (5 to 10 pounds), open excess wash water valve "E" and empty press of excess water, back to water supply or sewer.

13. When press is empty of excess wash water, which is indicated by sudden drop in pressure, close excess wash water valve "E" immediately.

14. Let air blow through cakes (5 to 10 pounds), and out of filtrate cocks for a few minutes for further drying of cakes. When cakes are sufficiently dry, turn off air at "C," release pressure on press through excess sludge line, open press and discharge cake.

(c) 15. The cakes can now be removed from the leaves by any one of several methods, *viz.*:

By washing the cakes off with a stream of water from a hose.

By vibrating or shaking the filter leaves by hand.

By using a wooden spade with a long handle.

By inflating the filter bags, through the filtrate outlets, with air or steam.

As soon as the filter leaves have been cleaned, the press is closed and is ready for another cycle.

The Kelly Press has been installed in a variety of industries in the last ten years although its original application was in the cyanide process and later in the beet sugar field. In chemical industries it has found a place in starch, aluminum, dyestuff, oils, pharmaceutical works, etc., in fact wherever the solids can be separated out under a pressure of up to 100 pounds, without seriously clogging the filter medium before a one-quarter inch cake is built up, and where the solids are not so heavy or coarse as to settle very rapidly, or in such abundance as to build up a cake in a few minutes time.

It is claimed for the Kelly Filter Press that it gives rapid filtration, rapid drying, small maintenance expense, high recovery of values, complete accessibility of all parts, no leakage, is semi-automatic, and allows the operator to inspect the cake before discharge.

On the other hand as the only agitation possible in the shell is by leaving the valve on the top of the shell open and while filtering to return some of the sludge back to the source of supply, there is a tendency for settling to occur, thereby causing an uneven cake to be built up and poor washing and drying to result. The presses are rather expensive to install, mechanically cumbersome and unless a substantial cake is built up they will not discharge easily and if a cake is built up rapidly constant labor is required to open and shut the press. Also the vertical position of the leaves makes careful attention necessary to hold the cake on the leaves and to get clean discharge.

Sweetland Filters.—The Sweetland Filter is manufactured by the United Filters Corporation. The machine enables a large filter area to be enclosed in a small space and as the leaves are not shifted at any time the only movable part is the bottom of the filter container which swings open for discharge. Like the other leaf filters this machine was developed in the West and was first used in the mining industry. It is now used elsewhere, particularly in sugar refining.

The Sweetland type of leaf filter is composed of a cast iron body mounted on cast iron supports as shown in Figure 198.

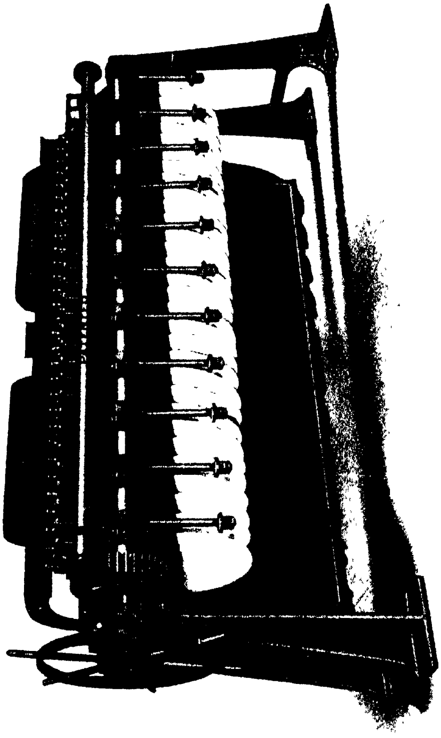


Fig. 198
Sweetland Filter

The body is divided along the horizontal axis and the two halves are hinged together on the back. The upper part is rigidly fastened to the supports and the lower part is allowed to swing, in order to open the filter for cleaning and dumping the cake. When closed, the swing bolts fasten the two halves together, a water-tight joint being formed by a rubber gasket in a groove in the joint forming the surface of the upper half.

The principal parts of the filter are shown in Figure 199, as follows, (1) the internal manifold pipe which may be used as a sluicing pipe, for cleaning off the cake from the leaves, or as an overflow pipe so as to create a circulation inside the filter during operation, or as a distributing pipe in the case of top feed, or in some cases to admit wash water, (2) the filtrate manifold through which all the filtrate passes, (3) sight glasses through which the filtrate passes from each individual leaf to the filtrate manifold, (4) the filter leaf covered with filter cloth, with a small portion of the cloth torn away to show the wire screen backing for the cloth, (5) distribution plate to distribute inflow of sludge and wash water, (6) the hinge which allows the bottom half to swing down and back out of the way when discharging the cake, (7) the leaf spacers fastened to the upper half of the body, (8) the swing bolts for locking the press when closed, (9) the filtrate shut-off cock, used to shut off filtrate if

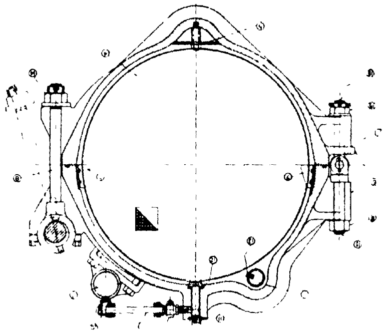


Fig. 190
Sweetland Filter (Section)

that particular leaf runs cloudy, (10) cap nut to fasten filter leaf with lead washer (11), on the outside and rubber washer, (12) on the inside, (13) nozzles used when operating manifold (1) as a sluicing pipe, (14) the swing bolt castle nut to adjust the length of the swing bolts as the gasket between the two halves of the body wears down, (15) the yoke hinge bolt, with its castle nut, (16), (17) the hinge pin, (18) the plain hinge bolt castle nut on the hinge bolt, (19), (20) the outlet fitting through which a swab may be inserted to clean the sight glass.

OPERATION

1. Close and lock the press.
2. Open valve on filtrate line.
3. Get sludge into supply line to filter.
    (a) If using pressure tank—turn on pressure.
    (b) If using pressure tank—turn on pressure.
4. Open inlet valve to filter.
5. Continue forcing sludge into filter until proper thickness of cake is obtained. Do not permit cake to build together.
6. Washing (first method) turn on wash water simultaneously with shutting off of sludge. Wash until desired results are obtained.
7. If cake is not to be washed, close inlet valve and empty filter of excess sludge, sending it back to the sludge tank.
8. If cake is to be washed (washing second method) get wash water into the supply line while emptying filter of excess sludge and see that all the pressure in the tank is not released, so the cake will stay on the leaves.
9. Open wash water valve to the filter, releasing air pressure through a valve on top of the filter. Wash until desired results are obtained.
10. When washing is finished, close inlet valve, open compressed air valve, open excess water valve and empty filter of excess wash water.
12. When filter is empty close excess wash water valve and let air pass through the cake to dry it or if a dry cake is not desired sluice the cake off the leaves and out through the outlet valve.

13. If a dry cake is desired, release air after drying, open the press and dump the cake.

14. The cake is dumped by blowing air in the reverse direction to the filtrate flow.

The Sweetland Filter is used in beet and cane sugar refineries, in the manufacture of syrups, beverages, food products, etc., as well as in metallurgical plants, chemical works, and dyestuff manufacturing. It is used on clarification when a filter aid such as filter-cel is added, for precoating the leaves or in the liquid to be clarified. Like other leaf filters the Sweetland is a filter wherein either the filtrate, the cake or both can be saved. It will be noted that the method of operating and the general principles of the Sweetland are very similar to those of the Kelly and in fact the machines are in sharp competition although they are now manufactured by the same corporation. It may be said therefore that like the Kelly the Sweetland is adapted for those slurries which are neither collodial nor very coarse and heavy nor where high pressures are required.

Its advantages also are those of rapid filtration, economy of floor space, accessibility, inspection of cake, low maintenance and good extraction especially as compared with plate and frame presses. The disadvantages likewise are, the difficulty of maintaining proper agitation with heavy solids, the tendency of the cake to fall off the leaves if the press is carelessly operated as the leaves are vertical, the difficulty of obtaining a wash unless carefully watched for the reason that poor agitation will cause an uneven cake to be formed and as the drainage is all from the top of the leaves, the locking of the shell often is difficult and a good deal of labor and attention is necessary throughout.

Vallez Filter.—The Vallez Filter manufactured by H. A. Vallez, is a pressure filter with rotating leaves. Like many other leaf filters it was developed in sugar refining. The particular feature about it is that the leaves are revolved as the cake builds up so that a cake of uniform thickness is produced. It is now being tried out in numerous industrial plants and where the cake is not to be saved very little attention is required for operation.

The shell enclosing the filter leaves is made of cast iron and is divided on the horizontal center into two parts, as shown in Figure 200 and 201. Figure 200 shows the filter closed ready for operation. On the upper half of the shell the spray pipe "a" passes through the top of the shell. This spray pipe serves to either blow off or flush off the cake, as required. The cake indictor is shown at "b," consists of a pointer and scale on the outside and a paddle on the inside of the filter between the leaves. The operator by shifting the indicator to right or left can determine the thickness of the cake at any time. The driving mechanism for the rotating of the leaves and the screw conveyor in the bottom of the shell is shown at the left "c" and the filtrate outlet at the right "d." At "e" may be seen a tube containing a hydrometer. In this tube the filtrate or wash water is kept running and the specific gravity can be determined by means of the hydrometer when desired. Inlet valve and outlet valve for the sludge and wash water are shown at "f." Valve "g" is used as an outlet when cleaning the filter by flushing with water. Overflow valves or air inlet valves, as the case may be, are shown at "h." A view of the other side of the filter is shown in Figure 201 with the top half of the shell removed exposing the rotating leaves to view. The shaft that

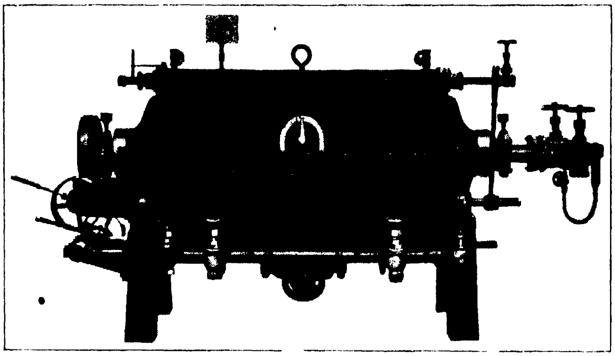


Fig. 200
Vallez Rotary Filter

serves as a filtrate outlet is also plainly shown. The discharge door on the bottom of the shell is used when the cake is to be discharged dry. The screw conveyors on the inside work right and left handed and bring the cake, after it has been discharged

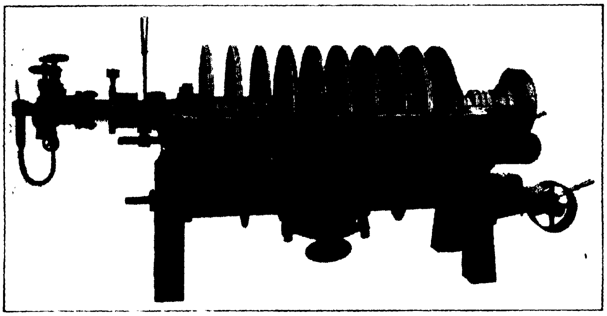


Fig 201
Vallez Rotary Filter

from the leaves, to the opening in the center of the bottom of the shell and it is then discharged from the filter. The leaves are made of steel or other metal. The supports for the filter cloth, either monel or fabric, are perforated plates on each side of a spider frame. The cloths are placed on this plate and fastened down by metal rings one on the outside and the other on the inside around the shaft. When the leaves are mounted on the shaft they remain in the same position at all times.

The operation of the Vallez is simple, as once the filter is closed ready for operation it need not be opened until the cloths need renewing, which is only after long periods, as they are cleaned inside the press. The cycle of operation is as follows:

1. Close al valves on filter except inlet and overflow valves.
2. Start driving mechanism to rotate leaves.
3. Start pump or turn on pressure if using pressure tank.
4. When sludge appears at overflow valve close valve.
5. Continue forcing sludge into filter until proper cake is built up or filtrate falls off too greatly.

6. Close inlet valve and open compressed air valve on top of filter, open excess sludge valve on bottom and force excess sludge back to supply tank. When pressure drops quickly, filter is empty, close outlet valve and air valve.

7. If cake is to be washed open wash water valve on bottom of filter and overflow valve on top (do not let pressure in filter drop to zero) to release air and when wash water appears at overflow close overflow valve.

8. When washing is finished close inlet wash water valve, open excess wash water outlet valve and open air valve on top of filter. This forces the wash water out of the shell, back to the water supply or to the sewer.

9. When filter is empty close outlet valve and let air at 5 or 10 pounds pressure blow through the cake to dry it.

10 When ready to discharge cake start mechanism that moves the screw conveyor, shut off air valve on top of filter, release air pressure by opening a valve on the bottom of the filter and open the discharge door on the bottom of the shell.

11. If the cake does not fall off of its own accord while the leaves revolve, apply air to the spray pipe or water if the cake can be mixed with water. The cake falls on the screw conveyor and is discharged from the filter.

12. If the cake can be discharged from the filter by flushing turn on the water in the spray pipe and air or steam in through a perforated pipe where the screw conveyor is located and wash the cake from the leaves.

The Vallez filter is one of the newest types and there is therefore a great deal of experimental work yet to be done in order to determine just what are its adaptations and its limitations. Where clarification is the object in view and there is a very small amount of solids present and a filter aid such as filter-cel, paper pulp, talc, etc., can be used, this filter is especially efficient as it does not need to be opened during any period of operation. It has had a great deal of success in the filtering of sugar juices, syrups, and oils, and is being tried out in various other industries.

It is claimed for this filter that it is labor saving, uses a small amount of wash water, saves filter cloths as they are washed in the filter and not removed until worn out, has low maintenance cost, is easily insulated, produces a very uniform cake, gives rapid discharge of the cake and quick washing of the cloths, any type of filtering medium can be used, and it is a very clean installation. The disadvantages would appear to be that, like other presses with upright leaves, if the pressure is lost the cake will fall off, intelligent labor is required to open and shut the valves, see that the press is drained, etc., and it is not adapted particularly to cases where it is desired to save the cake.

Zenith Open Tank Filters.—This type of apparatus is manufactured by the Industrial Filtration Corporation under exclusive license from the owners of the Moore patents. It had its greatest success in the cyanide industry where hundreds of thousands of tons of low grade ore and tailings were filtered daily. Its extensive use was due to the enormous spread of filtering surface and excellent wash with a small amount of wash water which could be obtained by these filters. The fact that the cake is built up by vacuum behind the filtering medium which vacuum is limited to about 28 inches gives a cake almost perfectly uniform in thickness and porosity. It also enables many semi-colloidal solids to be handled which would clog a filter medium under higher pressure. Open tank filters are used where slow filtering but not too slimy materials are encountered, which materials can be filtered by suction. In many cases they allow a finer grinding and consequently better extraction than could otherwise be employed. There are numerous installations in dye and chemical plants, especially in acid slurries as leaves and tanks can be readily constructed of acid resisting materials and any leakage which might occur would be inwards and not dangerous to workmen.

A frame supporting the filtering medium constitutes the leaf proper as is shown in Figure 202. Each unit or leaf consists of a pipe frame, usually in rectangular form, over which is drawn the filtering medium which has previously been sewn into the shape of a bag. The open and loose ends of the bag are held tightly together at the top by means of wooden clamps, thus requiring the stitching of only three sides and permitting the ready and easy substitution of new filter bags for old. The two sides of the filter cloth are held apart by parallel wooden strips set upright and the filtering medium is stitched in such a manner as to hold the strips in position. Along the bottom of the pipe frames are perforations, causing the suction to pull uniformly at all points behind the filtering medium. When used industrially a number of these leaves are connected together in the form of a basket and attached to a common header as shown in Figure 203.

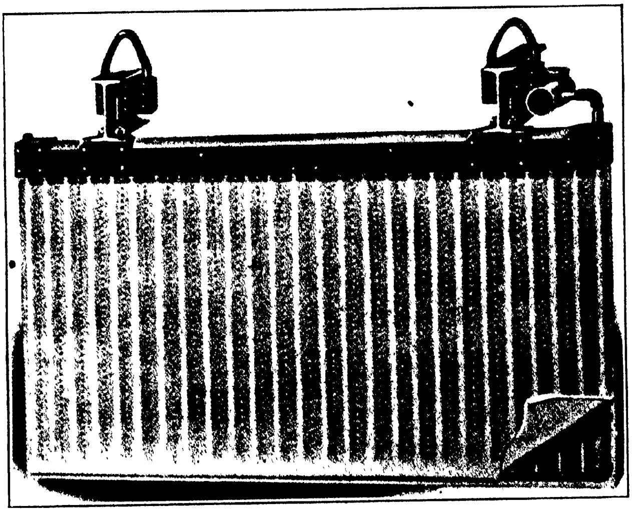


Fig. 202
Filter Leaf

To facilitate shifting of the basket a movable hoisting device is used and connection between the header and the vacuum line is made by means of flexible tubing. Open tanks are used for submerging the basket of leaves during filtration and washing.

Filtration is accomplished, by first lowering the basket of leaves until they are submerged in the solution to be filtered, and then applying suction behind the filtering medium, which causes the clear filtrate to be drawn through the filtering medium from the outside to the interior of the leaf and thence through the perforated pipe to the main header and from there to the desired point. The suspended matter is deposited on the surface of the filtering medium in a layer or cake. This is usually built up to a thickness of from one-half to three inches and the basket, suction still being kept on, is transferred with the adhering cake to a tank of clear water, if washing is desired. During washing the effluent can be switched to another tank, thus making possible separation of filtrate from wash water. After washing, the basket is shifted to the discharge platform and the cake is dried by drawing air through it. Discharge is accomplished by shutting off the suction and applying air, water, or steam pressure through the same line.

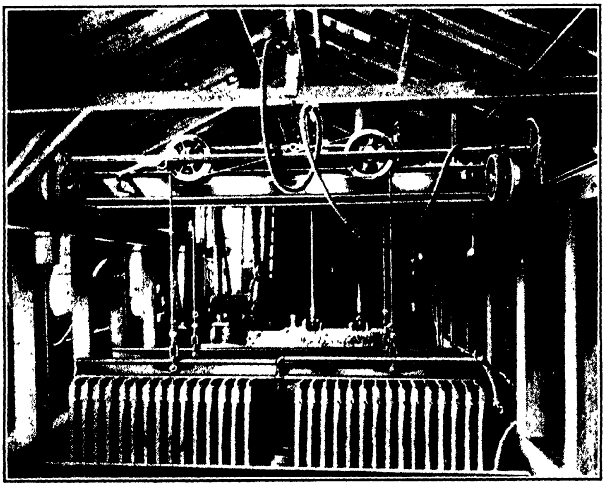


Fig. 203
Open Tank Filters

The open tank filter is adapted for materials which, though slow filtering, are of a crystalline or amorphous nature as ferric hydrate, ore slimes, manganese oxide, dyes, etc. The slow filtering rate may be due to fineness of the solids, their slimy nature, or because of impurities. Many semi-collodial materials can be handled provided a filter-aid is added to the slurry prior to filtration.

Some of the disadvantages of this type are that; a great deal of room is required both for tanks and for overhead shifting devices, care must be taken not to knock off the cake in raising and lowering the filter basket, the discharging by pressure blows back entrained moisture into the cake thereby increasing the moisture content, although this is true of all leaf filters, and finally unless a cake of at least one-half an inch is built up clean discharge can not be easily obtained.

On the other hand because of the suction behind the filtering medium and drainage at the bottom of the leaf a very uniform cake both in thickness and porosity is built up which cake is easy to wash and discharge. Any period of cake building, washing or discharge can be decided upon by the operator as the filter is open to inspection and control at all times and very large filtering area can be obtained at a low figure, which area can be increased at any time simply by adding more leaves The filter is cleaned automatically in discharging the cake, and as the operation is semi-automatic very little labor is required.

CHAPTER XII

ROTARY FILTERS

The greatest step forward in filtration has been the invention and development of the rotary filter. This is because the primary end in view with these filters has been, and is, continuous and automatic operation. The machines are thus especially efficient and economical and they have effected great savings in numerous plants by the practical elimination of labor and their low cost of operation and maintenance. Unfortunately they are limited to filtration by vacuum so that where high pressures are required or if there is less than 10 per cent of solids present they can not be used as a rule. The thin, uniform cake produced upon a rotary filter is easily washed with a small amount of water and readily dried, while the automatic cleaning of the filter medium during every revolution of the filter drum, upon the multiple compartment machines, gives very large capacities per square foot of filtering surface. Where washing is not required, or it is not necessary to separate the wash water from the filtrate and the rate of flow is not materially cut down by allowing a thin layer of solids to remain on the surface of the filter drum continuously, a filter drum with a single compartment, which is relatively cheap to install and has low maintainance costs may be employed.

There are two general types of rotary filters now manufactured; the disc type and the drum type. Of the former there is the American Continuous Filter and the Filtros Wheel, and of the latter the Glamorgan Rotary Filter, the Oliver Continuous Filter, the Portland Continuous Filter, and the Zenith Rotary Filter, in common use.

American Continuous Filter.—The American Continuous Filter is made by the United Filters Corporation and is one of the newer filters. It was designed as a space economizer to replace the drum type where the very large sizes, sometimes gone into in the mining field, occupied a great deal of room and were very cumbersome to handle. In plants of this kind the American Filter not only cut down floor space and head room requirements but are much easier to handle and cheaper to install. Industrially they have found favor where large filter areas are needed to handle a free filtering slurry, containing solids of a medium specific gravity and where the washing requirements were not very rigid. They are manufactured generally in sizes of 4-feet discs, to 8 feet 6-inch discs, one or more discs to a filter.

The machine, Figure 204, consists essentially of a number of filter discs mounted perpendicularly about a central shaft. The shaft with its assembly of filter discs is supported horizontally above a tank designed to hold the slurry to be filtered. The lower part of the discs dip into the slurry and the filtrate is drawn into the interior of the discs and carried away by conduits in the central shaft. Each disc is divided into a number of sector-shaped, independent filtering units, Figure 205, which vary in size and number according to the diameter of the machine. Each sector is interchangeable with any other and is held in place by radial rods mounted between adjacent sectors in the same disc. Each

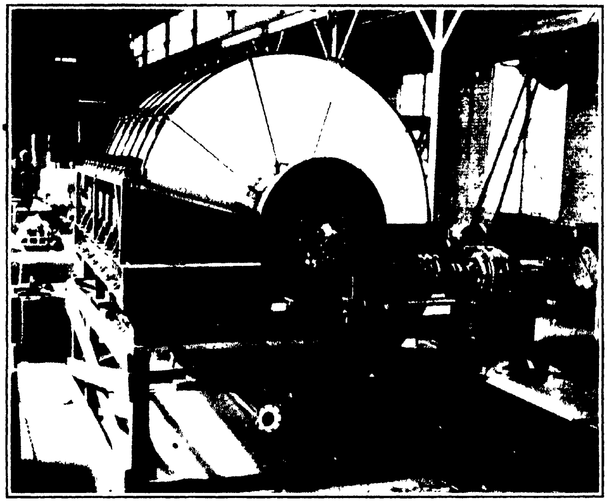


Fig 204
American Continuous Filter

sector is constructed of a rigid frame work, firmly holding a double-crimped wire body and having a projecting nipple that fits into a sectionalized joint designed to form a leak-proof joint with the ports on the sectionalized shaft. Each sector is covered with a cloth bag drawn over the frame, the outer edges being lapped and clamped by means of a strip of metal held in place by the clamps at the end of the radial rods The same filtrate conduit serves to drain all discs located in any given arc of rotation and as the discharge is controlled by means of a rotary valve, this valve may be placed at either or both ends of the sectionalized shaft. The gear is attached to this shaft and the shaft with filter

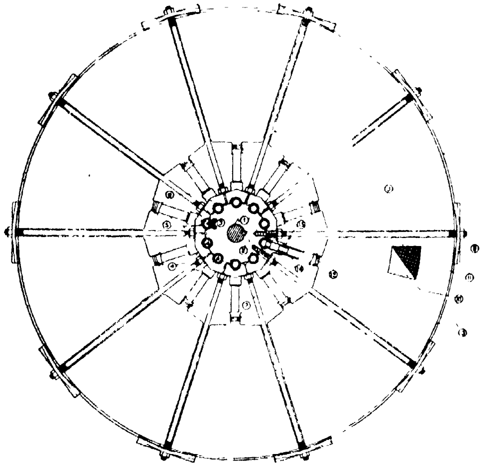


Fig. 205
Filter Disc—American Continuous Filter

1. Driving Shaft.
2 Key.
3 Frame Spider
4 Shaft Filtrate Conduits.
5. Gasket.
6. Saddle Castings.
7. Radial Rods.
8 Rod Clamps
9 Sector.
10. Filter Bag
11 Double crimped wire Drainage Screen
12 Cord Binding Neck of Bag.
13 Bag Clamp
14 Nipple Draining Sector
15 Rubber Washer.

discs is mounted in a quarter cylindrical tank One side of the tank is continuous and common to all discs while the other side provides for discharge of the cake by a number of separate extensions (pan spouts), one for each disc. The extensions and the continuous tank form the pulp tank proper and allow the slurry to surround the lower part of each disc. The spaces between the extensions provide for the discharge of the cake as it drops from the discs and falls to a hopper or conveyor placed below the filter. The upper edges of each extension tank carry scrapers which bear lightly against both surfaces of the filter bag (these scrapers are flexible and held together by means of springs at their outer edge) as the latter is bulged by air supplied to the interior of the sector

Operation is really composed of five stages as follows:

1st. Filtration which commences as soon as a sector is completely submerged in the pulp to be filtered. The difference in pressure required to produce filtration is obtained by applying vacuum to the interior of the sector through its filtrate line

2nd Washing the soluble material from the cake. This is done by maintaining the vacuum on the interior of the sector and projecting a fine mist-like spray of wash water against the cake-covered sector as it emerges from the pulp. A special spray device is supplied for this purpose to produce a very dense mist with so slow a velocity that furrows will not be cut in the cake.

3rd. Drying the cake. This is effected by continued vacuum on the interior of the sector after it passes through the washing zone.

4th. Discharging the cake. This is accomplished by admitting compressed air to the interior of the sector at the moment it starts to pass the scrapers. The air pressure varies from 5 pounds to 15 pounds, according to the size of the filter.

The pressure of the air on the inside of the bags loosens the cake from the filter cloth and presses the cloth lightly against the scrapers, thus insuring a thorough discharge of the solids.

5th. Exhausting to the atmosphere, the air left inside the sector at the end of the discharge period. The air pressure is simply allowed to escape to the atmosphere, thus reducing the load on the dry vacuum pump and saving power.

When it is unnecessary to wash the cake, operation 2 is done away with and the drying period as described in 3 is simply increased in length of time.

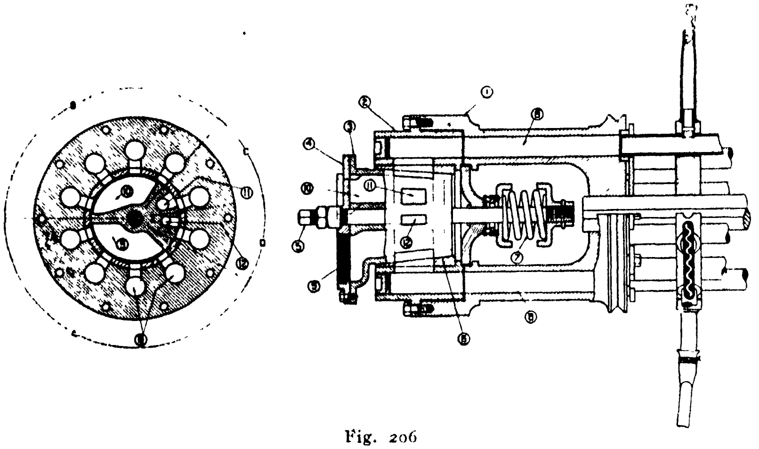


Fig. 206
Valve—American Continuous Filter

1. Valve End Journal
2. Removable Valve Housing.
3. Stationary Valve Plug.
4. Plug Cap.
5. Spring Regulating Screw.
6. Valve Bushing.
7. Spring.
8. Filrate Ports.
9. Filtrate Outlet.
10. Wash Water Outlet.
11. Compressed Air Inlet.
12. Air Exhaust.

These several operations are controlled by the valve which is shown in Figure 206. It will be seen that the end of the filter shaft terminates in a housing which is ground to fit over a conical valve plug having two recesses (9 and 10) and two openings or ports (11 and 12). The valve plug is stationary and the housing which connects with the filtrate lines rotates. Recess (9) on the under side of the valve plug connects, with all lines carrying sectors which are completely submerged in the pulp and controls the vacuum required for producing filtration.

Following recess (9) is recess (10), which leads to the wash water suction and drying line and connects with all lines carrying sectors which are passing through the washing and drying period.

Port (11) admits low pressure air to all sectors which are passing the scrapers.

Port (12) allows the low pressure air contained in the inflated sectors to escape into the atmosphere before these sectors pass into submergence.

Each sector after passing the scraper is again submerged in the pulp tank and the cycle is repeated.

The American Continuous Rotary Filter is adapted to dewatering propositions particularly, for it enables large volumes to be handled quickly and easily. This class of work is found in the mining field and industrially where large quantities of solids must be partially dried to cart away.

The machine economizes space, is light to ship, the main operating valve is self-seating and hence tends to regrind itself and as no wire winding is used this item is eliminated in recovering. The cloths are scraped clean every revolution of the discs, leaks can easily be detected in a single sector, and in common with other rotary vacuum filters a thin cake is built up and the operation is continuous and automatic.

The machine has, however, the disadvantages of poor agitation, tendency of discs to get out of alignment and necessity of recovering each sector separately which is a tedious operation. The scraping against the cloths wears them out rapidly and a heavy cake is difficult to keep on the sectors particularly if it cracks. Washing on a vertical disc is hard to accomplish efficiently, the lack of protective wire causes the filter medium to be strained by the air pressure, and the expense of maintenance is usuallly higher than that of the drum type.

Filtros Wheel.—The General Filtration Company manufactures a disc rotary filter consisting of a single wheel with filtros plates fastened to it as the filtering medium. This filtros is a white, rigid, porous, mineral substance composed essentially of silica, the filtros analyzing 99.6 per cent SiO_2. The sand after being screened is fused with a synthetic silicate at 2,000° F. and cast into various shapes, usually not over 12 inches square or 1½ inches thick. The outstanding feature of the Filtros Wheel is this mineral filtering medium which obviates the necessity of changing the filter medum and thus reduces the maintenance cost.

In principle the filter is virtually a wheel, Figure 207, with shaft, hub, spokes and rim. The wheel is divided into sixteen separate compartments and for convenience is cast two compartments to a segment, thus requiring the assembly of but eight segments. Each compartment is completely isolated from the others, the only means of communication being through holes in the compartments and through corresponding ones in the hub "AC" and 'AD," Figure 208, to the valve plate "E." Each com-

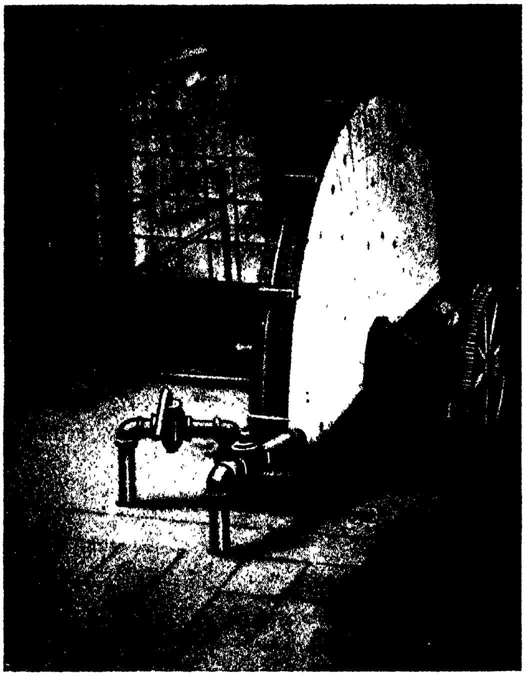


Fig 207
Filtros Wheel

partment carries through its center a flat vertical web "CD," cast therein and covering the entire area except at the hand-hole "D" (this hand-hole is shown only on Figure 208, it being provided merely for use in emergencies should it be required to reach the radial holes "AD" in the hub. It extends outward for a distance of 4 inches from the hub end on one side of each compartment and sacrifices but little filtering area, the opposite side "DA" being cast in solid).

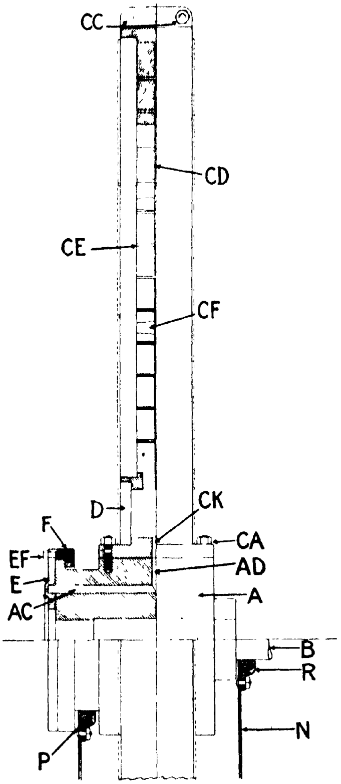


Fig. 208
Filtros Wheel

The web carries at right angles on both sides a series of concentric webs "CE," also cast in and spaced about 3 inches apart, which serve as a firm and rigid support for the filtering medium proper, which covers both faces of the wheel. The segments are not truly symmetrical, but radiate from the hub at such an angle as to bring the outer radial walls of each segment to very nearly a horizontal position, about 4 inches above a horizontal center line of the wheel. This is done because the cake discharges at this point, and because by such an arrangement the entire compartment is immersed in the pulp by the time the hub end is, and no vacuum is thereby lost by having a bare plate exposed to the atmosphere. As the wheel rotates the effect is that the rim end of the segment travels ahead of the hub end. The hub is bored, both axially "AC," Figure 207, and radially "AD" with sixteen holes, each one of which registers with a hole "CK" in the hub of each segment when assembled, so that the course of discharge from the wheel is through said radial and axial holes to the valve plate "E." This latter is ground to an air-tight connection with the face of the hub "AA," Figure 209, and has internal channels which register with the axial holes of the hub. The valve plate "E" is ring-shaped, fitting loosely around the shaft, and is always stationary, while the face of the hub "A," Figure 209, rotates against it, being held in place by an angle-shaped valve ring "F," Figure 208. The outer face of the valve plate is provided with connections for the vacuum "VD" and air lines "VB," Figure 207.

The standard size wheel is 10 feet in diameter for the actual filtering surface making a total diameter of 10 feet 6 inches. The filtros filtering medium is bolted to the face of the wheel through center holes in each shape, ten shapes to a compartment, the retaining washers being counter sunk so that the faces are smooth. The seams between shapes are filled in with cement.

In operation the slurry to be filtered is fed continuously into the container and suction applied behind the filtering medium through the valve hub. The solids are deposited on each side of the wheel as it revolves and are carried around through the air, where sprays may be applied for washing, to the point of discharge. The cake is here automatically scraped off and dropped to a receptacle below. As the compartments are separate, discharge may be aided by air or steam pressure, which in addition

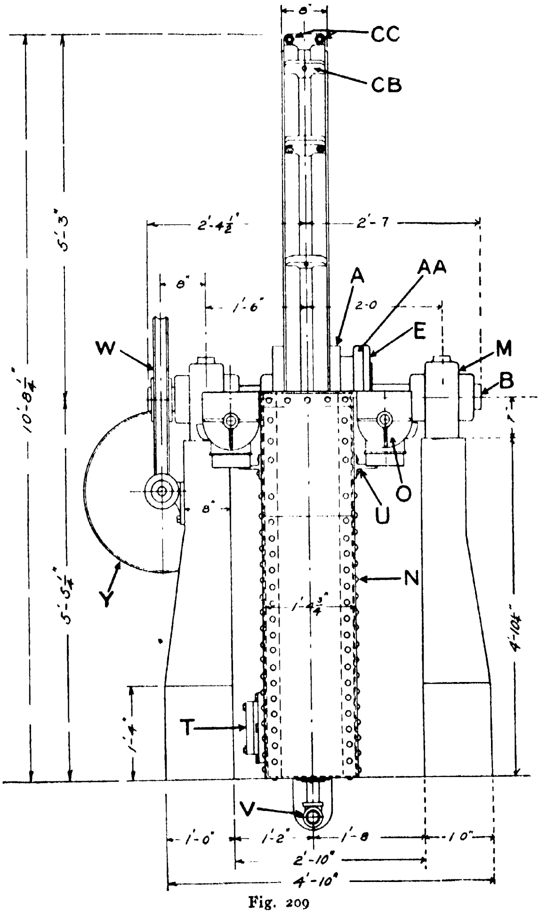


Fig. 209
Filtros Wheel

keeps the filtros filtering medium clean. Also a separation can be made of filtrate and wash water if desired.

The Filtros Wheel can be used wherever rotary suction filtration is possible, except where clogging of the filter medium comes after a few days' time, which clogging cannot be overcome by back washing and scrubbing. It is especially useful where strong acid or alkali solutions are to be handled as the frame can be constructed of acid or alkali resisting materials and the filtros filter medium is inert chemically.

It is claimed for this machine that it has the advantages of large filtering area in a small space (several wheels can be connected together if need be, each being 10 feet in diameter), chemical inert filtering medium, strength, rigidity, permanence of filtering medium and consequently low up-keep, and in common other continuous and automatic filters labor is practically eliminated.

The apparent disadvantages are that of weight (approx. 9,000 pounds for the 10-foot wheel), the necessity of assembling at the plant, the difficulty of replacing the sections when the filtros becomes clogged, poor agitation, trouble in washing because of the vertical position of the wheel, and the expense of installation.

Glamorgan Improved Rotary Continuous Suction Filter.—The rotary filter, Figure 210, manufactured by the Glamorgan Pipe &

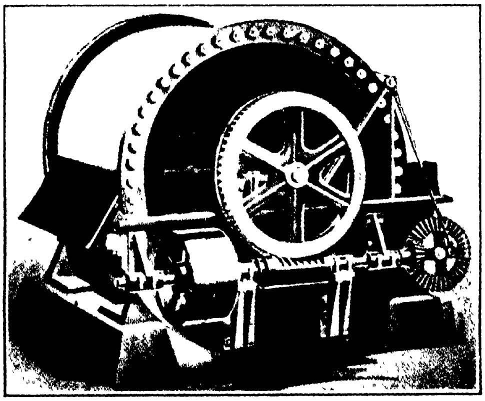


Fig. 210
Glamorgan Rotary Filter

Foundry Company is the heaviest and most expensive of rotary drum filters. It is constructed of castings, carefully machined. The filter is made in two sizes, one 6 feet in diameter with a 3-foot face and the other 3 feet in diameter with a 1½-foot face. It has a low container and closed ends. A single spider supports the drum, the arms of the spider acting as drain arms for the liquor. There are thus no pipe lines and the whole drum, which is made up of two or three castings machined and bolted together, is without danger of leaks or breakage. The compartments are kept separate and distinct by cross rods and the container is equipped with a rocker agitator.

The filter has the advantage of low cost of renewal and repair especially high efficiency and the other features of the rotary filters, but is so heavy and expensive that it is not in extensive use.

This machine is adaptable for handling mud from hot caustic solutions from continuous causticizing and lime recovery, bicarbonate of soda, salt from continuous discharge vacuum pans, kaolin, feldspar and all other purposes where filters of the revolving type are suitable.

Oliver Continuous Filter.—The Oliver Filter, a drum type of rotary filter, made by the Oliver Continuous Filter Company, was originally designed for the recovery of gold-silver solutions from ore slimes in the cyanide process. The application of these machines has since been made to the different industries. The Oliver filter is very light in construction and cheap to install which is of particular importance to mining companies having low grade tailings running to waste which can only be saved by automatic filtration.

The filter, Figure 211, consists of a drum or cylinder, rotating on a horizontal axis, with the lower portion submerged in a tank containing the pulp to be filtered. The surface of the drum is divided into compartments or sections, the dividing partition being parallel to the shaft. These compartments are covered by a screen for supporting the filter medium which is held in place and protected from wear by a wire winding. Each section of the drum is connected by pipes passing through a hollow trunnion to an automatic valve which controls the application of the vacuum for forming and washing the cake, and the admission of air for its discharge. Thus each compartment forms virtually an independent unit although the filtering medium is attached as a continuous sheeting over the whole surface of the drum. Provision is made for applying such washes to the cake as may be needed for complete replacement of solutions. A scraper is fitted across the tank and rests on the wire winding in such a manner that the barren cake is removed after being released by air or steam pressure. An agitator suitable for the pulp to be handled is placed in the bottom of the tank to keep in suspension the heavier particles of solids and to insure a uniform cake.

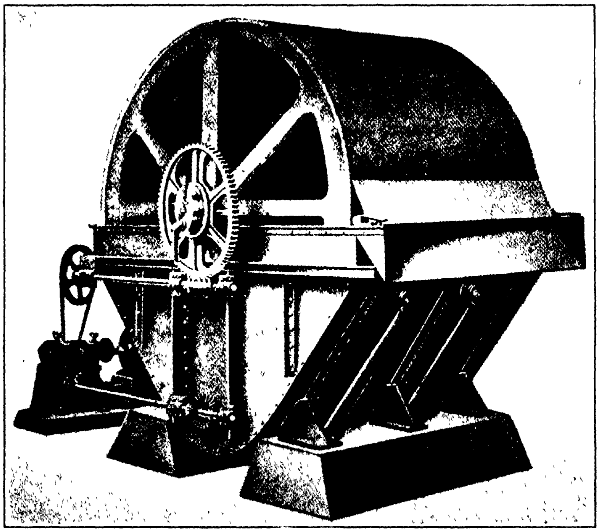


Fig. 211
Oliver Continuous Filter

If the solution contains salts which tend to crystallize or clog tank in a steady stream. A homogeneous mixture is maintained by agitation, either mechanically or by the use of compressed air or steam. As the drum rotates the filtering surface is passed through the agitated mass. Immediately each compartment under vacuum is immersed, a cake begins to build and continues building to the point of emergence from the pulp. The liquid passes through the filter medium and the vacuum pipes to the automatic valve, while the solid particles adhere to the drum surface in a thin uniform cake.

As soon as the solution disappears beneath the surface of the cake, the wash may be applied. This effects a thorough wash without mixing of solutions. The automatic valve can be ad-

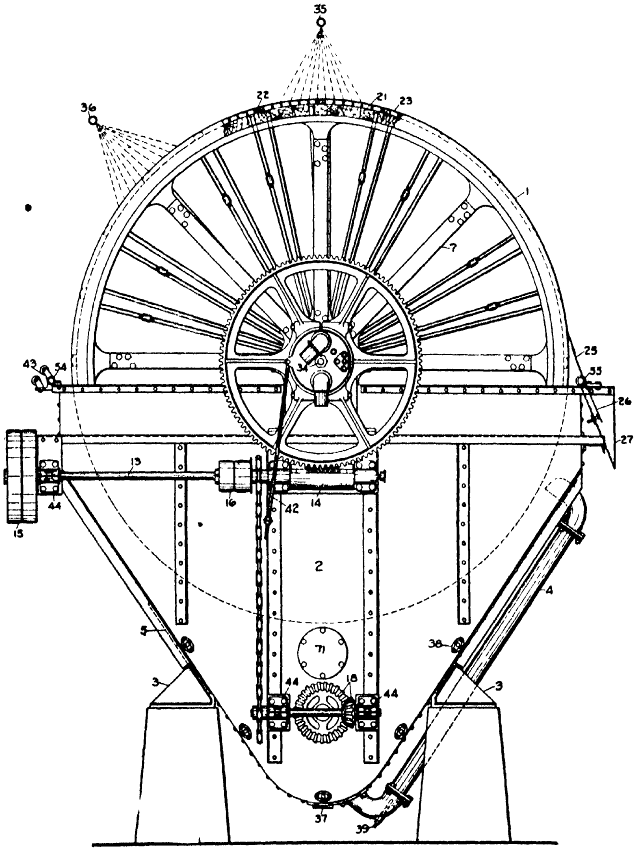


Fig. 212
Oliver Continuous Filter (Section)

1. Filter Drum
2. Filter Tank.
3. Tank Feet.
4. Air Lift Circulators.
5. Tank Manhole.
6. Channel Steel Drum Rim.
7. Channel Steel Drum Arms
8. Hollow Cast Iron Trunnion.
9. Steel Drum Shaft
10. Main Bearings.
11. Agitator Stuffing Boxes.
12. Worm Drive Gear.
13. Worm Shaft.
14. Oil Well for Worm.
15. Filter Drive Pulley.
16. Wiring Pulleys
17. Chain for Agitator Drive.
18 Bevel Gears.
19. Agitator Shaft.
19a Agitator Stub Shafts.
20. Agitator Shaft Bearing.
21. Wood Staves—Drum Shell.
22. Division Strips.
23. Filter Medium.
25. Steel Scraper.
26. Scraper Adjusters.
27. Discharge Apron.
32. Vacuum Connection.
34. Valve Steam.
35. Wash Water Sprays.
36. Wash Solution Sprays.
37. Drain Flange.
38. Emergency Air Pipe.
39. Airlift Nozzles.
42. Valve Adjuster.
13 Wire Spacing Nut.
41 Worm Shaft Bearings.
45 Wiring Sprockets.
51 Wiring Screw Bearings.
55 Scraper Bearings.

justed so that one or more washes may be given and the filtrates kept separate.

As the drum continues to rotate and a given compartment passes out of the wash zone, the vacuum is cut off, compressed air is automatically turned on by a different port in the valve, the cake is loosened and cleaned off by the scraper, and a clean filter surface passes forward to immersion and the commencement of a new cycle.

If the solution contains salts which tends to crystallize or clog the filter medium, steam or additional air may be admitted through another port. These ports are controllable from the outside of the automatic valve without stopping the filter.

The whole process is therefore continuous and automatic, and there is no break in the various stages of the cycle.

In the Oliver, as in other suction rotary filters, the vacuum can be cut down when the cake emerges into the air and thus prevent cracking by shrinkage before washing can be applied. The machines are made with drums ranging from 3 feet to 24 feet in diameter with faces from 6 inches to 24 feet. They are made with open and closed ends, rocker or paddle agitation, as the occasion may demand, and constructed in wood, iron, brass, etc., according to the slurry to be handled.

The filter is continuous and automatic, it builds a uniform, homogeneous cake rapidly, washing clean with a small amount of wash water, is simply and lightly constructed.

On the other hand the two sets of pipe lines are without union connections and therefore difficult to get at for cleaning from leaks in the medium or deposition of solids from the solution. The air line has a tendency to become filled with liquor which is blown back into the cake, the pipe lines in the standard machines are so small that air locking occurs, and the maximum capacity, wash or dryness of cake is not obtained. The driving gear situated over the valve causes excessive wearing of the valve and the light construction throughout gives quite high items of repair and renewal.

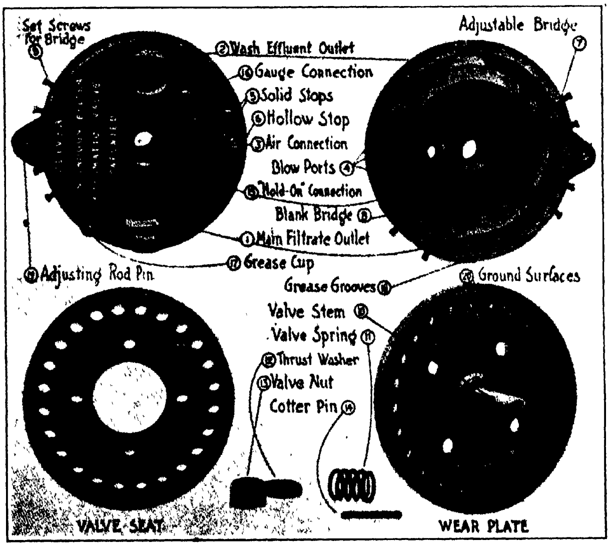


Fig 213

Valve Oliver Continuous Filter

Fig. 213 shows the essential parts of the Rotary Automatic Valve. The valve seat and renewable wear plate are bolted to the end of the trunnion and revolve with the drum, each hole corresponding to a filter section The valve is held true on its seat by the valve steam and the coiled spring

Portland Continuous Filter.—The Portland Filter manufactured by the Colorado Iron Works is very similar in appearance and construction to the Oliver Filter and like the Oliver was originally designed for handling ore slimes. The first machines were all composed of a twenty-two compartment drum, 12 to 14 feet in diameter and 5 to 14 feet in face. Later many other sizes were added but little change in general design has been made. The main points of difference from the Oliver are that the valve has but a single row of holes and a single line of pipes connect each compartment to the valve hub, the driving gear is on the opposite side from the valve, the compartments are kept separate and distinct by cross strips set in grooves between each compartment,

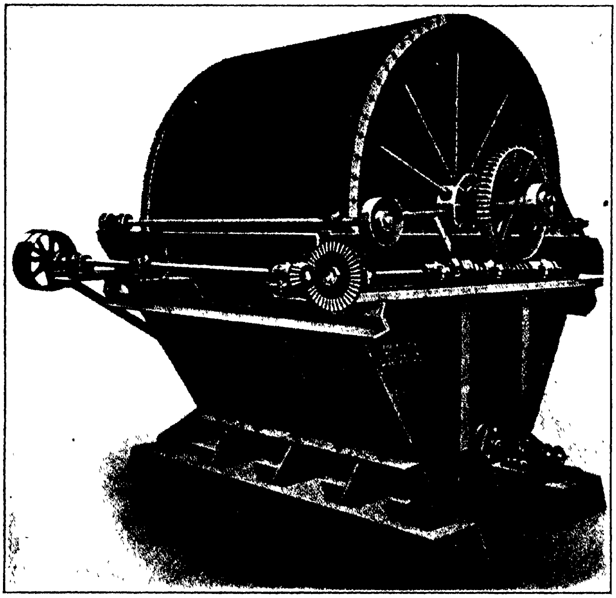


Fig. 214
Portland Continuous Filter

and the wire winding is soldered to the cross strips every few turns.

The machine, Figure 214, is composed of a series of compartments, carrying a porous filter medium, arranged in the form of a drum which is adapted to rotate in a tank containing the material to be filtered. Each compartment or section, which united make up the drum, is entirely independent of the others, and its action is controlled by an automatic valve which serves the whole machine.

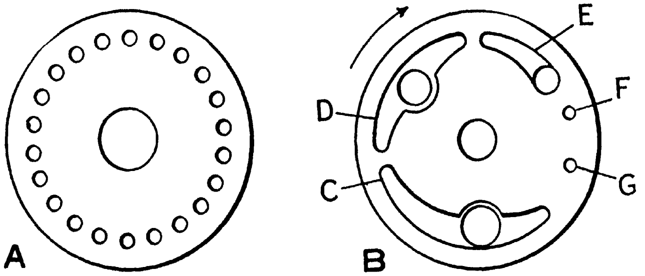


Fig. 215
Valve—Portland Continuous Filter

The Portland filter valve construction is shown in Figure 215. A filter 12 feet in diameter has twenty-two compartments, each connected with a single pipe which serves for both vacuum and pressure. These pipes pass through the bearing on one side of the machine and terminate in the valve seat which rotates, the valve being the stationary member.

The entire drum, Figure 216, is wound helically with wire, leaving the filter surface exposed between the convolutions, which are about one-half inch apart. The wire cloth "C" is a permanent part of the compartment, only the burlap "F," and drill "G," together with the winding of wire requiring renewal.

The working face of each compartment is provided with a moulding, "B," making a recess in which the wire cloth "C," lies separated from the face of the drum. Within the space inclosed by the moulding, wood strips "D," are fastened, these acting as supports for the wire cloth and providing drainage space for the liquid. The pipe which serves each compartment has two connections with this space through the back, so that drainage is complete whether the compartment is rising from the tank or descending into it. Grooves "E," leading to the pipe connections, aid the flow.

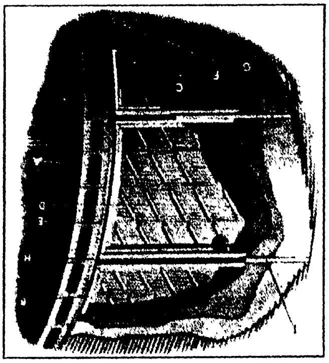


Fig 216
Portland Continuous Filter—Showing Construction

It will be noted that between the moulding upon one compartment and that upon the next there is a space "H." The canvas, although continuous, does not pass from one compartment uninterruptedly to the next, but is carried down to the bottom of the narrow space "H," and held there by a small strip "I."

The rotating valve seat shown at "A," in Figure 215, the actual surface of the seat being a renewable steel plate.

The stationary valve "B," is scraped to an air-tight fit with its seat, being held in contact with it by a spring. It contains ports controlling the operation of the machine, as follows: "C" is a port which connects with all the compartments which are submerged in the pulp; "D" is a port into which all the pipes from the ascending compartments open: "E" connects with all the compartments in the earlier part of their descent; "F" connects with each compartment in succession as it reaches the point of discharge, admitting air under pressure to dislodge the cake; "G" is another air pressure port connecting with each compartment just as it enters the pulp, to give the filter medium an additional cleansing action while submerged, before it again comes under the influence of the suction applied through "C."

"C," "D" and "E" being separated from each other it will be seen that the solutions drawn through these ports can be collected separately.

Material difficult to wash can be loaded under a moderate vacuum through "C," producing a porous and easily permeable cake, the washing being made much more thorough by a higher vacuum through "D" and "E." The stationary valve has a limited motion about its center, and by means of a lever and quadrant can be adjusted to bring the compartments under the influence of suction and pressure at the right points.

Adaptation to specific conditions is readily brought about by the regulation of a number of variable factors, such as depth of pulp carried in the tank, speed of revolution of the drum, and regulation of the vacuum.

In operation the lower part of the drum is submerged in the material to be filtered and is slowly rotated—one revolution in five to eight minutes—taking on a layer or cake of solids which is discharged before the same portion of the filter surface again enters the pulp. To build up the cake and remove the clear liquid vacuum is maintained, and to assist in discharging the cake and cleanse the filter medium a pressure of air is admitted to the interior of each compartment at the proper point in the cycle of revolution. A scraper maintained in contact with the working face of the drum, just above the top of the tank on the descending side, receives the cake as it is dislodged by the air and deflects it outside the tank for disposal. The cake may be washed prior to discharge by means of sprays or perforated pipes.

The Portland filter is now made in sizes ranging from a drum 6 feet in diameter with a 2½-foot face to one 14 feet in diameter with a 20-foot face. Although it has lately been applied to the industrial field the greater number of installations are in mining plants. It is adapted to handle large capacities of free filtering slurries having above 10 per cent of solids present and which solids do not require a large amount of air for drying.

The advantages claimed for this machine are continuous and automatic operation, light weight for shipping, and large sizes. A thin uniform cake is built up which is easy to wash with a small amount of water, and a single set of pipe lines to each compartment discharges a dry cake. Each compartment is distinctly separated from the next so that when air pressure is used for discharge there is no danger of it leaking under the canvas to the next compartment. The soldering of the wire does not require entire rewinding when a break occurs and the driving mechanism does not wear on the valve.

The disadvantages are that the small pipe lines reduce the capacity and increase the wash water and moisture content especially where very free filtering slurries are encountered, the whole construction is so light as to make the cost of maintenance high, and the low container used makes large sizes necessary to handle relatively small capacities.

Zenith Rotary Filter.—The Zenith Rotary Filter is made by the Industrial Filtration Corporation under exclusive licenses from the Moore Filter Company. The machine was designed primarily for industrial work and therefore the large sizes of the Oliver and Portland are not gone into and in the 8 feet in diameter and under sizes, large pipe lines, heavy construction, etc., is specialized in to meet the industrial requirements. The Zenith filters have met with a great deal of success where materials are rather hard to handle by rotary filtration or high capacities are desired per machine or where especially dry cakes are needed.

The Zenith Rotary Filter, Figures 217 and 218, consists of a hollow drum mounted upon a horizontal axis, the lower portion of the rotating drum dipping into the container holding the slurry to be filtered. The outer surface of the filter drum is divided into a number of uniform shallow compartments, each compartment being connected by separate pipe lines to the central valve hub which is cored out to receive the pipes from each compartment. The compartments are covered with wire screen suitably supported and over this, encircling the entire drum is stretched the filtering medium, each compartment being kept separate and distinct and giving a smooth peripheral surface to the drum.

The central valve hub rotates against a stationary valve cap which is so arranged that each compartment can independently be subjected to suction, or neutral, or pressure during any portion of the cycle. Provision is made in the valve cap for applying suction and for drawing off the filtrate and wash water separately if desired.

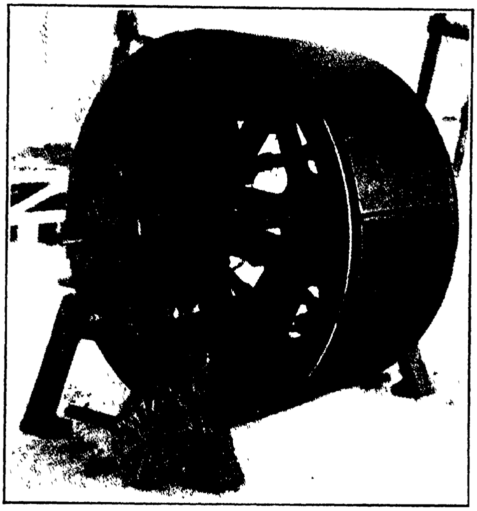


Fig. 217
Zenith Rotary Filter

The container in which the drum rotates is hopper-bottomed and provided with a mechanical agitator for keeping the slurry in a constant state of agitation during filtration. A scraper is fitted to the edge of the container, parallel to the axis and set at a very short distance from the face of the drum. It is the purpose of the scraper to remove the cake from the surface of the drum just before that portion of the drum is about to dip into the solution. Washing of the cake is accomplished by sprays which are so placed as to play upon the surface of the drum just after the drum with its accumulated solids emerges from the container.

The solids, held upon the filtering surface by suction, pass out of the slurry, are washed by the sprays and discharged over the scraper as a dry cake in the form of a ribbon from whence they may be conveyed as desired.

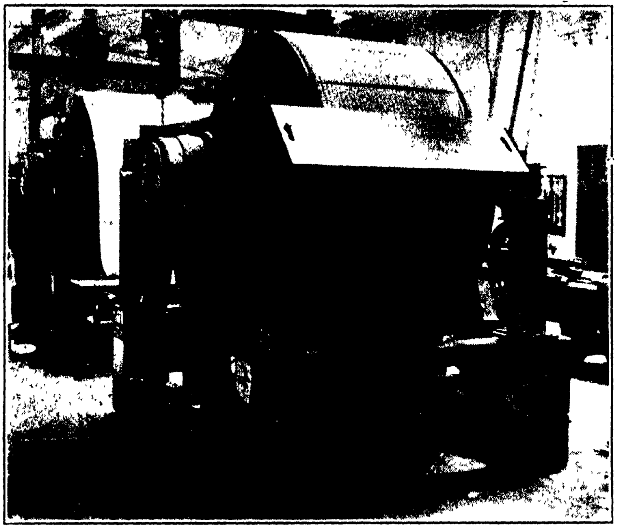


Fig. 218
Zenith Rotary Filter

The surface of the filtering medium is protected from abrasion by wire which is wound around the drum in the form of a helix with a hitch of a few inches. All parts of the machine are sturdily constructed; the castings are perfect, the wearing surfaces nicely machined and ground. The drum is driven by a large worm gear on the opposite side from the valve.

Every part of the filter is easily accessible. The pipes are extra large and the valve sector-shaped so as to readily take care of the large amounts of free air and filtrate which are drawn through the filtering medium.

The drum usually is rotated at the rate of about one revolution in five minutes. The container is kept filled with the slurry to be filtered, the excess being taken care of by an overflow pipe, and the solution is kept in agitation by means of the mechanical agitator. Vacuum is maintained by a dry vacuum pump or other means of creating suction of ample capacity to take care of the filtrate plus the free air which is drawn through the filtering medium. When operated with a dry vacuum pump, a tank acting as a receiver for the filtrate, is interposed between the pump and the filter. This tank is first exhausted by the pump and suction to the filter is applied from here The suction causes the clear filtrate to be drawn through the filtering medium, large pipes and valve to the receiver.

From here the filtrate may be removed continuously and automatically by means of a centrifugal pump or intermittently by cross connecting two receivers.

The solids are drawn by the suction on to the face of the drum forming a uniform layer or cake. As the drum rotates this layer or cake adhering to the surface of the filtering medium emerges from the solution and suction being maintained, the mother liquor is drawn out of the cake.

When the mother liquor disappears from the surface of the cake (should washing be desired) the cake is subjected to wash water delivered from sprays arranged a few inches above the surface of the drum. A sheet of water is thus spread over the cake so regulated that no water runs back into the container. The suction causes this water to be drawn through the cake replacing the mother liquid held in the pores of cake. Should it be desired to keep the wash water separate from the original filtrate, the former may be led off separately through the specially designed valve to the proper receiving tank.

After passing the zone of sprays the cake is air dried before being discharged over the scraper. Just before reaching the scraper, however, the suction is automatically cut off from that particular compartment. At times it is advisable to apply a blast of air to the compartment at the point of discharge in order to open the pores of the filtering medium as the cake is removed

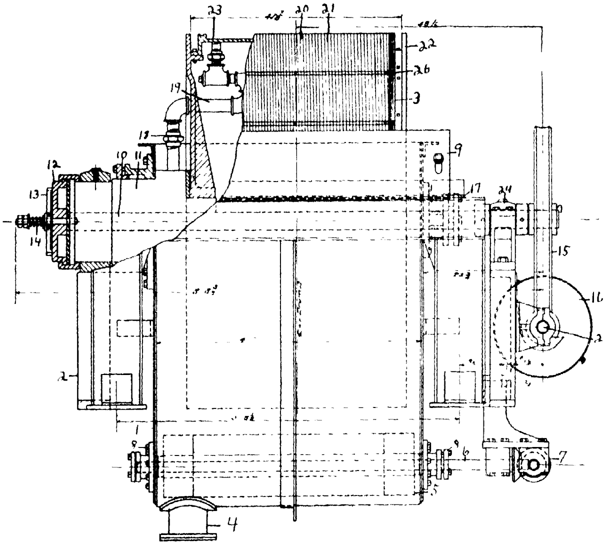


Fig. 219
Zenith Filter (Section)

1. Tank.
2. Leg Supports
3. Filter Drum.
4. Tank Valve Outlet
5. Agitator.
6. Agitator Shaft.
7. Agitator Mitor-Gear
8. Agitator Stuffing Box
9. Scraper.
10. Drum Shaft.
11. Valve Hub.
12. Valve Cap
13. Valve Cap Star
14. Valve Cap Spring
15. Worm Gear.
16. Pulley
17. Drum Stuffing Boxes.
18. Compartment Pipe Union
19. Compartment Pipe.
20. Filter Medium.
21. Wire Winding.
22. Drum Spiders.
23. Compartment Floor.
24. Drum Shaft Bearing.
25. Worm.
26. Cross Rods.

thus leaving a clean medium with which to begin a new cycle. As the cake is discharged over the scraper in the form of a ribbon, it may be dumped into a receptacle and carried away at intervals or it may be fed onto an automatic conveyor and thus collected continuously.

The attachment shown in Figure 220, may be used either on a low or on a high container filter. It consists primarily of a series of rolls resting on and turning a traveling endless belt. There are two adjustable springs for each roll so that the desired pressure may be exerted. The effect of these rolls, which are turned by the turning of the filter drum, is to squeeze down upon the cake and rearrange the normal piling and iron out cracks.

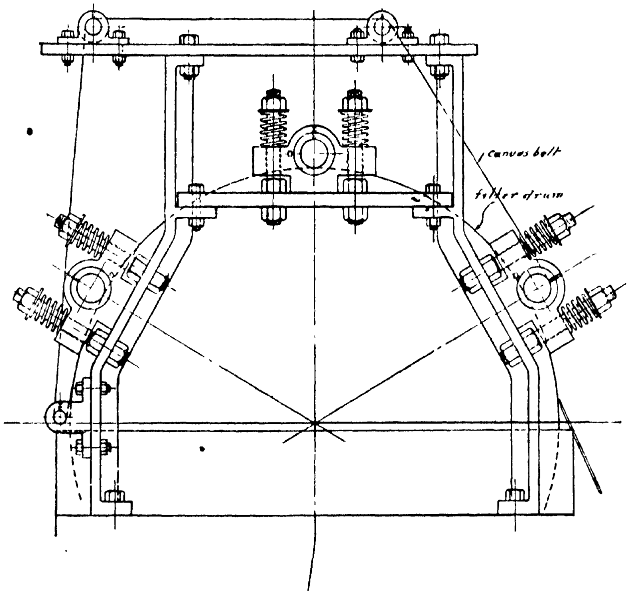


Fig 220
Pressure Roller Unit

This squeezing of the cake is carried on simultaneously with the suction beneath the filter medium so that a marked reduction in the moisture content of the cake can be obtained. This is very essential in the filtering of starch or clay where a dry cake must be had.

The Zenith Rotary Filter is made with either open or closed ends, paddle or special agitation, and low or high containers. This last is of importance as it allows of a 60 per cent submergence of the filter drum and consequently a greater capacity and easier wash, as the water is applied when the surface of the drum approaches the horizontal. The filters may be constructed of wood, iron, monel metal, aterite, hard lead, brass, copper, etc., and thus meet the local conditions. Because of the large pipe lines the machines are suitable for starch, bicarbonate of soda, cyanamid, and like materials, which require large volumes of air for drying the cake, beside the general run of materials that can be handled by suction rotary filters.

The advantages of these rotary filters are continuous and automatic operation, high capacities, and a thin cake which is uniform in porosity and density. A small amount of wash water is needed, a very dry discharge cake is obtained especially where the pressure rolls are used, and the strong substantial construction gives low maintenance costs. Large pipe lines with union connections, large valve and large worm gear on the opposite side from the valve, one set of pipe lines for air and suction, distinctly separate compartments by the use of cross rods, and practically no loss of vacuum between valve and filtering medium are other assets.

The filter has the disadvantages of being too heavy for easy shipment to distant or remote places, it is not made in the large sizes demanded by many mining companies, and like other rotary suction filters solids of a high specific gravity sluff off the drum as it emerges into the air.

Other Types.—The Glamorgan Company makes a single compartment rotary filter which is of the same heavy construction as their multiple compartment machine. The filter is made in two sizes 6 feet in diameter with a 3-foot face, and 4 feet in diameter with a 2½-foot face.

The Industrial Filtration Corporation also makes a single compartment filter consisting of a drum with closed ends, hung in a container like a multiple compartment machine, and having a

U-shaped stationary pipe extending almost to the bottom of the drum, which pipe passes through stuffing boxes on each side for connection to the suction line. This is a very cheap machine to install particularly where special construction is necessary to resist corrosion.

There is a filter made in Europe of the multiple compartment type called the Bruna Filter which has a single pipe terminating in the center of the bottom of the drum in contact with which each compartment must come. Such a machine makes draining rather difficult. The same sort of a filter is also made by the Societe Philippe in France but has not been very widely used.

In conclusion it may be said that rotary filters have the great attractiveness of continuous and automatic operation and the consequent elimination of labor. Where a one-quarter inch or better cake can be picked up on the surface of a filter drum in 3 minutes' time or better and properly dried in the same space of time, there is no question but that some type of rotary filter should be employed, the requirements of washing and of drying can be readily taken care of, one way or another as can any other requirements which are demanded. The materials which are being handled by rotary suction filters include such slurries as caustic lime mud, bicarbonate of soda, paper pulp, cyanamid, gypsum, cement, salt, saccharate of lime, clay, coal screenings, gun cotton, ore slimes, lime sulphur, lead arsenate, etc.

There is often the misconception that vacuum rotary filters cannot be used on hot slurries. This is far from the case as there is sufficient condensation in the pipe lines to allow a high vacuum to be maintained, especially since a dry vacuum pump with intermittent receiving tanks is used for creating the suction. In fact the majority of vacuum rotary filters in plant operation are handling hot or close to boiling slurries; *viz.*, caustic lime mud, saccharate of lime, etc.

CHAPTER V

CENTRIFUGAL MACHINES

The centrifugal machine, or extractor, as it is sometimes called, is ordinarily used either for the separation or extraction of liquids from solids or for the separation of two or more immiscible liquids. Centrifugal extraction and centrifugal filtration, which are alike, accomplish the removal of the solids from the liquids by passing the liquid through a substance which will retain the solids, while centrifugal clarification is a process of stratification by subsidence, the liquid passing through no obstructing medium. Inasmuch as centrifugal clarification takes place by virtue of the difference in densities of the solid and liquid components, liquids mutually miscible or soluble cannot be separated by centrifugal force.

The centrifugal force developed on materials to be separated may be many thousand times gravity, but it is always perfectly uniform at a constant distance from the center of rotation. Each individual particle of liquid is pulled away from the solids by this force so that the separation is easily accomplished. Whether or not a filtering medium should be used depends upon the material to be handled, as some materials are of such a character that even under high centrifugal force an impenetrable wall will be built up by the solids against the filtering medium almost immediately, thus cutting off all rate of flow, while in other materials the particles are so small that they are carried through the finest practical medium. There are also mixtures of different densities or sludges that cannot be filtered and must be separated by the action of centrifugal force alone.

Where a filtering medium is used it may be a side sheet of the centrifugal basket or a very fine filter screen placed inside the basket and in either case its distance from the center may vary within wide limits. If no filtering medium is used centrifugals with special accessories and with baskets without regular perforations in the side sheets are used. In centrifuging the denser liquid or materials form a layer or cake against the wall of the revolving basket and the liquids are removed continuously through nozzles.

De Laval Centrifugal.—The De Laval Separator Company which is one of the oldest companies in this line of business makes what are called De Laval Multiple Clarifiers, De Laval Centrifugal Filters, and De Laval Oil Purifiers.

The presence of small foreign particles and uncut gum or unground pigment in varnishes, japans and pigment goods are very troublesome to the manufacture of these products and in order to clarify such materials multiple clarifiers have been developed. The clarifiers not only give a clear smooth product but the high centrifugal force to which the materials are subjected gives a very intimate mixing, which is especially desirable

In the manufacture of certain very high-grade varnishes, and lacquers and oils used in their manufacture, as well as some base oils used in the manufacture of printing and lithographing inks, the use of the clarifier does not result in perfect clarity of the filtrate and for this work centrifugal filters were designed The centrifugal filter is often used following the clarifier, which removes the heavier solids, so that the filter has only the flocculent matter in suspension to handle.

De Laval Oil Purifiers properly come in Chapter VIII but as they are very similar in operation to the De Laval clarifiers and practically the same in construction, it might be well to mention them here while the other machines are being described. No lengthy discussion is given concerning them in Chapter VIII, it being sufficient simply to bear them in mind while reading about the clarifiers.

The De Laval centrifugal machines consist essentially of a cast iron frame, provided with suitable bearings for supporting a vertical shaft or spindle, which carries the bowl at the upper end. The weight of the bowl and spindle, together with any thrust due to driving, is taken by two tread wheels on which the lower end of the vertical shaft rests. Surmounting the bowl are two covers. The top one, known as the overflow cover, is provided so that if at any time the product is fed into the machine in greater quantity than the bowl can take care of, the surplus is discharged into the overflow cover. This keeps the overflow separate and acts as a warning signal that too much is being fed to the machine. The second cover receives the clarified product from the bowl and delivers it through the second spout to a hopper or other suitable arrangement.

The De Laval centrifugal machines are made in two general types—belt drive and turbine drive.

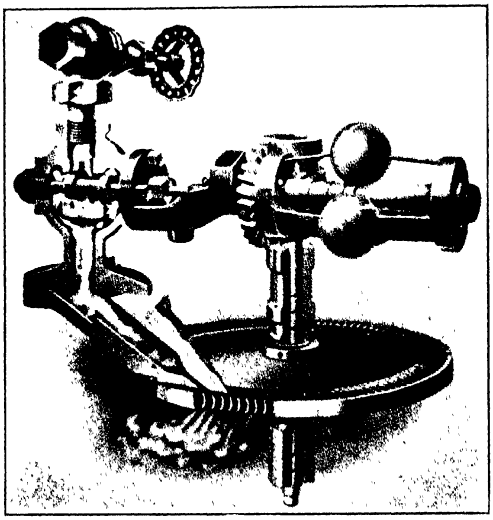


Fig. 78
Driving Mechanism—De Laval Centrifuge

The belt-driven types can be furnished with an electric motor mounted directly on the frame and connected to the driving mechanism by a short belt. The power in the belt-driven type is transmitted through a worm wheel and worm to the spindle and bowl. (Figure 79).

The turbine-driven machine is equipped with a steam driving wheel similar in principle to that utilized in steam turbine engines.

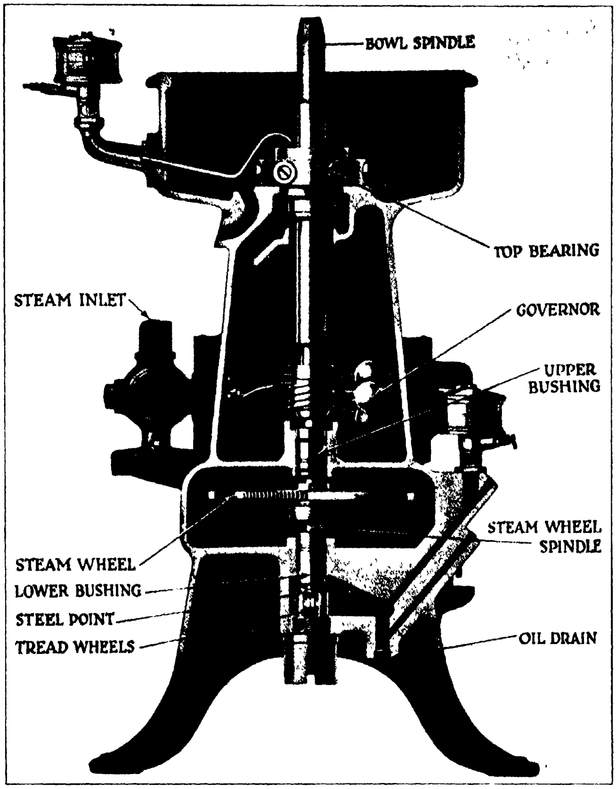


Fig. 79
De Laval Centrifugal (Section)

An important feature is the steam governor, similar to that used on high-class steam engines, which insures a constant speed of the turbine

The details of construction are shown in the cross-section illustrations Figures 79 and 80.

The features so far described are identical in the clarifier and the filter. It is only in the design of the bowl, which performs the actual work, that the machines differ.

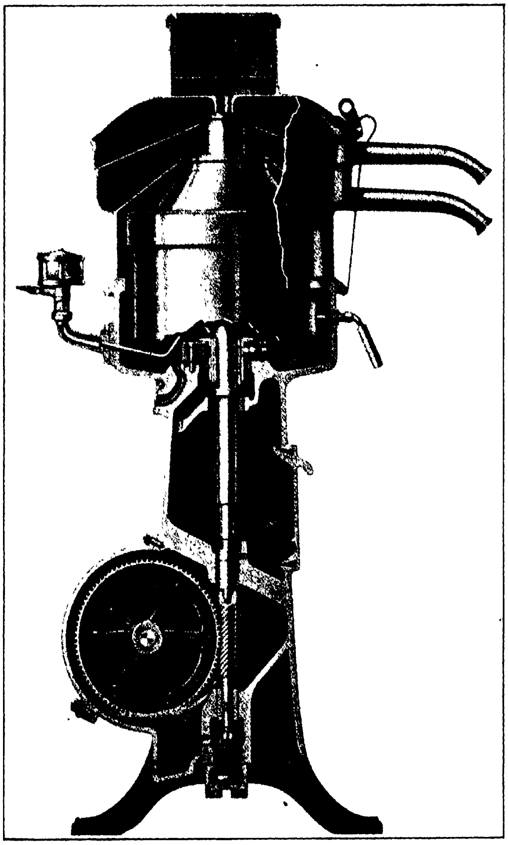


Fig. 80
De Laval Centrifugal

It will be readily appreciated that the smaller the diameter of the bowl the greater the speed at which it must be run to develop a certain centrifugal force and the larger the bowl in proportion to the amount of liquid to be run through it at a given speed, the higher will be the centrifugal force.

Figure 81 shows a cross-section view of the multiple clarifier bowl. The product to be clarified is fed into the top of the bowl

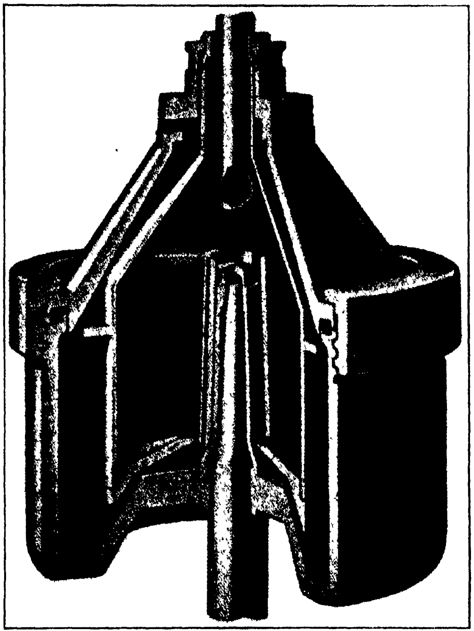


Fig. 81
De Laval Bowl Clarifier (Section)

and first enters the inner chamber, where the heavier and more easily separated solids are thrown out and held in the sediment pockets. The semi-clarified product then passes into the second, or outer, chamber where, by reason of the greater diameter, a maximum centrifugal force clarifies it of the finer and more difficult-to-remove particles. The clarified product is then forced upward to the discharge outlet.

An advantage of this construction is that the easiest-to-remove impurities are taken out in a separate chamber, so that when the partly clarified fluid is subjected to the intense centrifugal action of the outer chamber, the minute particles remaining in the liquid are removed without interference from the heavier ones.

The filter bowl, as illustrated in Figure 82, consists of a two-compartment bowl, the inner compartment being filled with corrugated plates. Between the plates is placed filter paper or other suitable filtering medium.

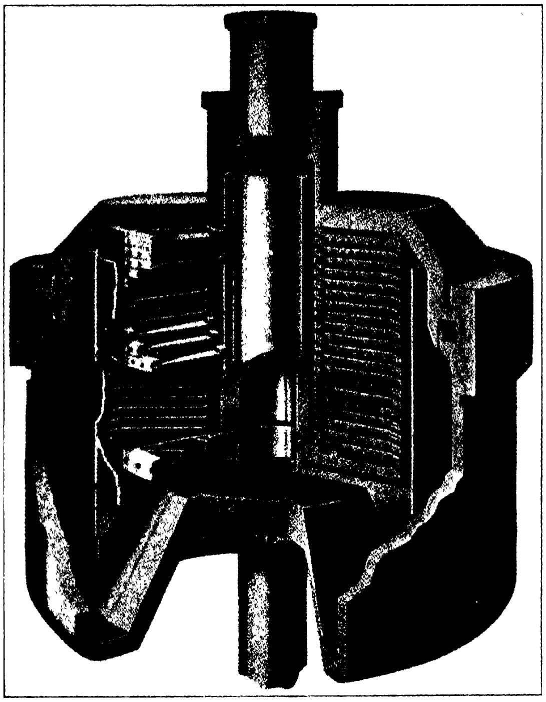


Fig. 82
Filter Bowl - De Laval Centrifugal

The product to be filtered passes into the top of the bowl and flows to the bottom, where it is forced out to the outer, or clarifying, chamber. Here the heavier and more easily removed particles are forced against the outer wall of the chamber. The partly clarified fluid passes to the inner chamber, where it enters the openings in the several plates, percolating under slight vertical pressure through the filter paper and thence inward and upward to the discharge outlet.

The principal advantage of this construction is that the filter is self cleaning, because the centrifugal force cleans the surfaces of the filter papers and throws the impurities out to the dirt-holding space. This insures long runs before it is necessary to stop and change filters.

The bowl is easily cleaned, as the filtering plates are removed in one piece and require disassembling only when it is necessary to put in new filter papers

It is not desirable as a rule to revolve the De Laval machines at a speed exceeding 6,000 to 8,000 revolutions per minute as above this speed they are exposed to excessive wear and generally have a short life. The machines give good service and a clean separation where they can be employed and do not consume excess horsepower or labor.

Elmore Continuous Centrifugal Machines.—The Elmore Continuous Centrifugal, manufactured by G. H. Elmore, belongs to the filtration or hydro-extractor class of centrifugal machines. It is of the basket type and belt driven. The pulley for driving may be seen at "A" Figure 83, fastened to a shaft which carries a beveled gear. This in turn drives a bevel pinion with differential spiral gears attached to the hub. The pinion rotates on a stationary counter-shaft. The distributing cone with scraping flights and distributing paddles (Figure 84) is driven by one spiral gear and the screen basket (Figure 85), on the inside of which is attached the screen, is driven by another spiral gear. The scraping flights and the basket with the screen, rotate in the same direction, the basket rotating slightly faster than the scraping flights due to the differential gears.

In Figure 83 is shown at "b" a hand wheel which is used to revolve a screw in the bottom of the lower bearing support, which raises or lowers the internal spindle carrying the scraper

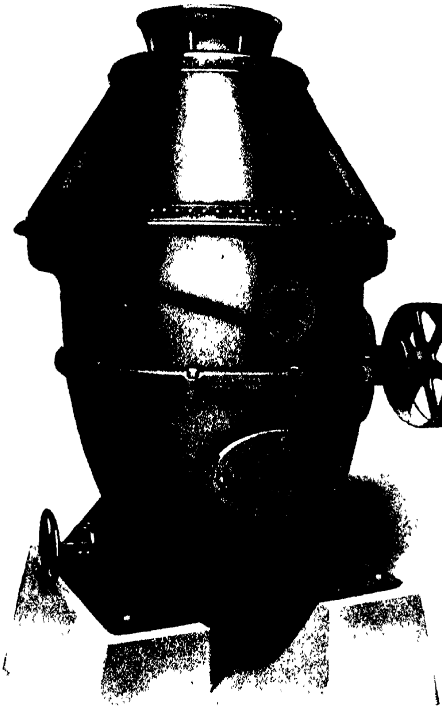


Fig. 83
Elmore Centrifugal

flights. This enables a filter bed of material to be maintained on the screen clear of the material while the machine is in operation. The standard basket for the Elmore centrifugal is a truncated cone (Figure 85) cast in one piece and forming the base of various combinations. The screen or filtering medium depends on the nature of the material to be handled.

In operation the slurry to be centrifuged must be uniformly fed into the hopper (c) Figure 83 and the distributing paddles will feed the material evenly onto the top of the distributing cone.

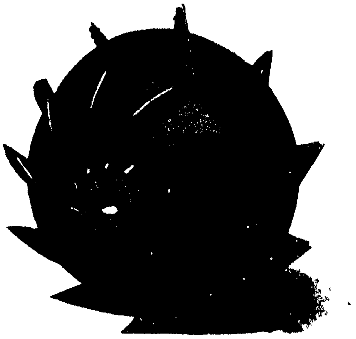


Fig 84

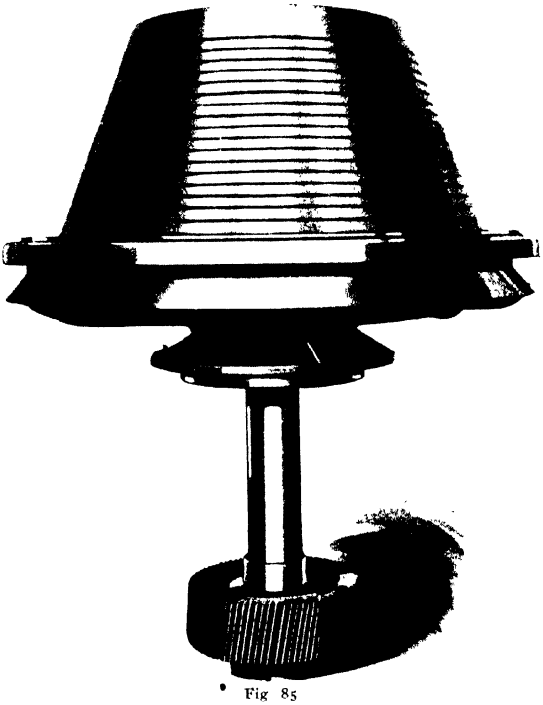


Fig 85

The material is immediately thrown against the screen, which is held by the basket, where the liquor passes through the perforations of the screen and strikes the liquor shield and is deflected into the liquor launder surrounding the base and drains out through two suitable outlets (d) on opposite sides of the machine. The solid material is forced down the screen by the scraping flights which are inclined at an angle to the horizontal and are helical in form. It is then discharged into the opening, bounded by a renewable ring, and is thrown by centrifugal force against this ring, from which it gravitates through the annular openings between the outer wall of the base casting and the spherical oil-tight gear case and is discharged through the bottom of the machine.

Continuous centrifugals may be used wherever centrifugal force can be employed for the separation of solids from liquids. The advantages of this type are that the operation is continuous, so that power is cut down (no starting and stopping) the number of machines required is less, floor space is less and labor is practically eliminated. The time of dehydration is shorter than in batch centrifugals as the size of the cake can be limited by the scraper. The size of the cake also means the total weight of material being treated in the machine is less and there it exerts a smaller centrifugal force on the screen.

The machines are of course more complicated in construction than non-continuous centrifugals and consequently the cost of maintenance is higher. The machine is expensive to install and care must be taken to prevent accidents with a complicated apparatus of this kind running at high speed.

Resines Process.—Centrifugal sedimentation by the Resines process is controlled by the Cresson-Morris Company and is devoted primarily to the sugar industry. There are no filter cloths used and the machine is run at a normal speed so that it does not need extra heavy construction. The centrifuge (Figure 86) developed for sugar work was an adaptation of the Bac Portal settling tank, which consisted of a long tank with several vertical baffle plates causing the juice to take a sinuous course alternately down and up through the tank.

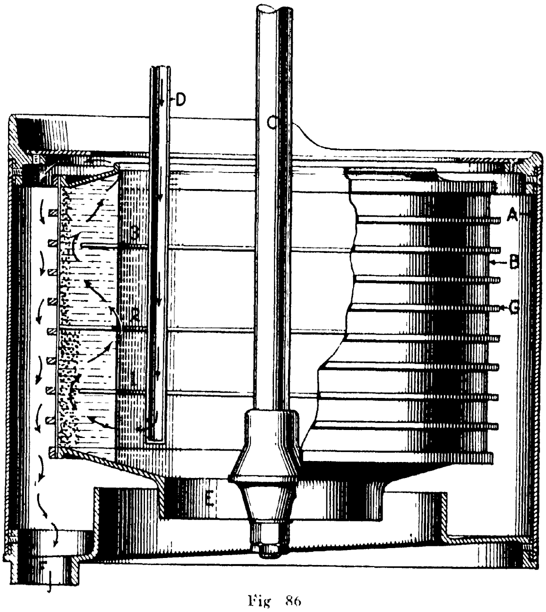


Fig 86
Resines Centrifugal Separator

In the Resines Centrifugal Separator the liquid enters near the bottom of the rotating basket through pipe "D." After the basket has been filled, additional quantities are obliged to travel a sinuous path until discharged. During the time of their travel the centrifugal force acts on the liquid and suspended solids in the ratio of their respective specific gravities. As the course of the sinuous path is determined not only by the baffle plates, but also by the rotation of the machine, the liquid travels in a helix, the length of which is determined by the velocity of rotation of the basket and the rate of admission of the arriving liquid. If the velocity of rotation remains constant, the time during which the liquid remains in the machine can be regulated by the inflow until the resultant liquid is free of suspended matter.

A 40-inch standard centrifugal separator will hold when filled to the brim 60 gallons of liquid. About two-thirds of this space may be regarded as a sedimentation chamber, which gradually becomes filled with suspended matter. The actual capacity of the machine is therefore 20 gallons; and if the rate of flow is 30 gallons per minute the liquor will remain in the basket for 40 seconds. During this time it will have traversed a helical course of several thousand feet, being subjected to a force from five hundred to six hundred times that of gravity. The liquid originally contained in the sedimentation chamber, of course, is gradually replaced by solid particles but not rapidly enough to materially affect the rate of flow.

The Resines centrifugals possess the great advantage of speed when compared with settling tanks and while, like other centrifugals they consume a good deal of power and labor, they are a great improvement over old methods. The boiler-house efficiency is increased by the removal of the impurities in the raw sugar and the crystallization is improved so that if a plant has hitherto been unable to get rid of the foreign material in the raw juice this type of apparatus will show very decided economies.

Fletcher Centrifugal Extractors.—The centrifugal extractors formerly made by Schaum and Uhlinger are now manufactured by the Fletcher Works. The machines are used for extraction of liquids in dye works, bleacheries, grain and milk sugar refineries, crystalline salt, fertilizer, emery, and chemical works, for separating coal dust, culm, ore, sand, etc., for removing liquid from hides, pelts, jute, hemp, pulp, general and hotel laundry, piece goods, bathing suits and clothing, and for reclaiming paint, oil, and grease.

The sizes of machines run the same as other hydro-extractors (30, 36, 42, 48 and 60 inches) and they may be turned by a direct connection, electric, steam, or friction drive, above or below or they may be driven by belt or hand.

The extractors have various designs for special work, as the piece goods extractor (Figure 87) has a rotating table instead

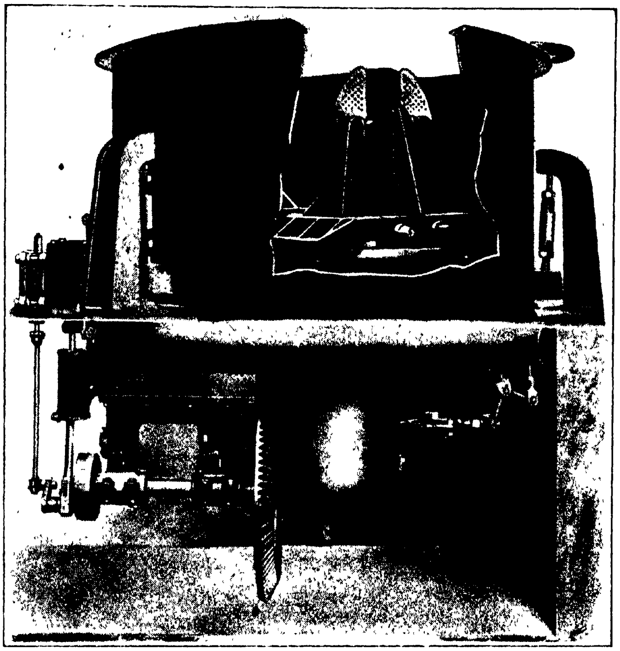


Fig. 87
Piece Goods Extractor

of the usual basket. This table is fitted with an adjustable frame for holding the goods on the roll and these rolls can be changed according to the size needed.

The Fletcher centrifugals do not differ from other machines of this type except in the fact that the Fletcher Works specialize in textile extractors (Figure 88) for drying of various piece materials as clothes, hides, etc., rather than simply in the separation of solids from liquids.

Sharples Super-Centrifuge.—The Sharples Specialty Company make a centrifuge called the Sharples Super-Centrifuge which

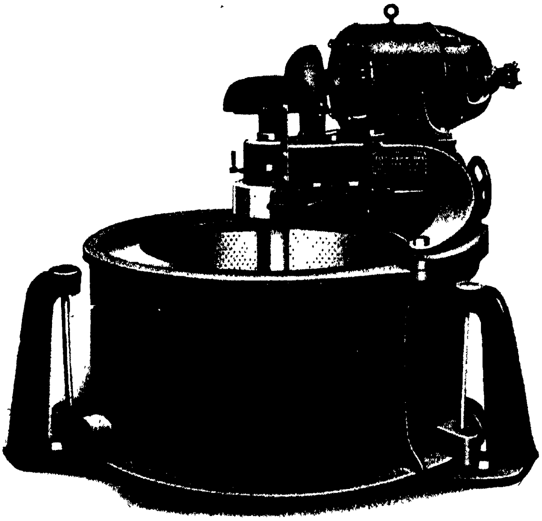


Fig. 88
Textile Extractor

separates solids from liquids or two liquids of different specific gravity by means of highly intensified subsidence. The commercial machine operates at a speed of 17,000 revolutions per minute and thus exerts a separating force 16,950 times the force of gravity.

The machine (Figure 89) consists of a rotor (1) known as the "bowl," 36 inches long, 4½ inches in diameter, hung in vertical position from a flexible spindle (2) fixed at its upper end, the spindle rotating in the ball bearing (3), from which the whole assembly is suspended. At the lower end of the bowl is a guide bushing which restricts any tendency of the rotor to oscillate out of the perpendicular. The bowl itself is a plain cylindrical tube, closed at its upper end with the bowl head provided with the outlet ports, and at its lower end with the bowl bottom containing the inlet port. It is equipped with a removable set of wings which serve to keep all parts of the liquid at the same speed of revolution as the bowl. The bowl bottom may be readily removed

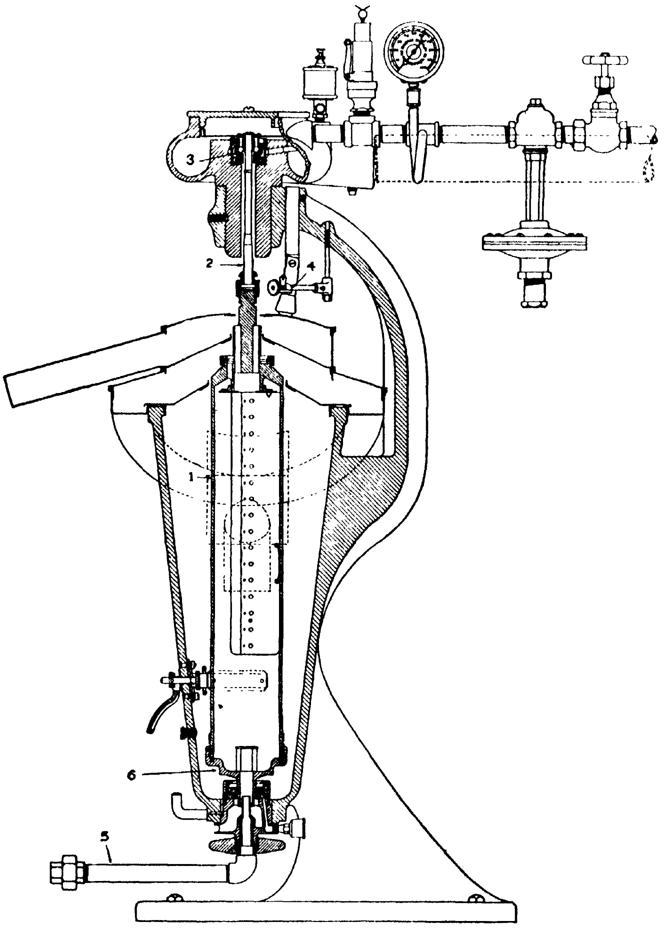


Fig 80
Sharples Super-Centrifuge

so that the interior is accessible. The bowl head through which the treated liquor is discharged is designed and constructed in each case to meet the requirements of the particular process.

In operation the power is first applied and the bowl is brought to its operating speed. There is a speed indicator (4) by which the speed of the bowl is determined.

The liquor to be treated is fed usually by gravity from an overhead constant level tank, through the feed pipe (5) into the bowl through the bowl bottom at (6). The liquor is instantly brought up to the speed of the bowl, and as a result forms a cylindrical wall against the shell of the bowl.

Occasionally a problem of clarification presents itself, in which part or all of the suspended solids are lighter than and float upon the liquid. In this case these solids collect at the center where they form a core. A baffle is then provided just below the discharge ports and the liquid is drawn from somewhat below the surface.

Inasmuch as the suspended matter which has been separated from the liquid forms either a cake or a core within the bowl, when approximately 15 pounds of sediment has been accumulated the machine is stopped by the application of a brake. The bowl is then removed, the bottom is taken off and the bowl itself cleaned, either by hand or with special apparatus; and the machine reassembled and started.

The Sharples Super-Centrifuges of clarifier type (Figure 90) are machines designed for the clarification of liquids in which the liquid passes through the bowl continuously, the separated solids being retained in the bowl.

The liquid enters the bowl forming a cylindrical column within the bowl. The application of centrifugal force separates the suspended matter which forms a solid cake on the wall of the bowl.

In settling by gravity the clearest liquid is always at the upper surface and if settling is carried on continuously the discharge leads from the upper surface. The analogous method is used in centrifugal clarification. In the latter case the top surface is the inner surface of the liquid wall (the baffle being removed in such cases) and the discharge ports in the clarifier bowl draw from this inner surface. The force of gravity being so much less than the centrifugal force generated it is actually negligible.

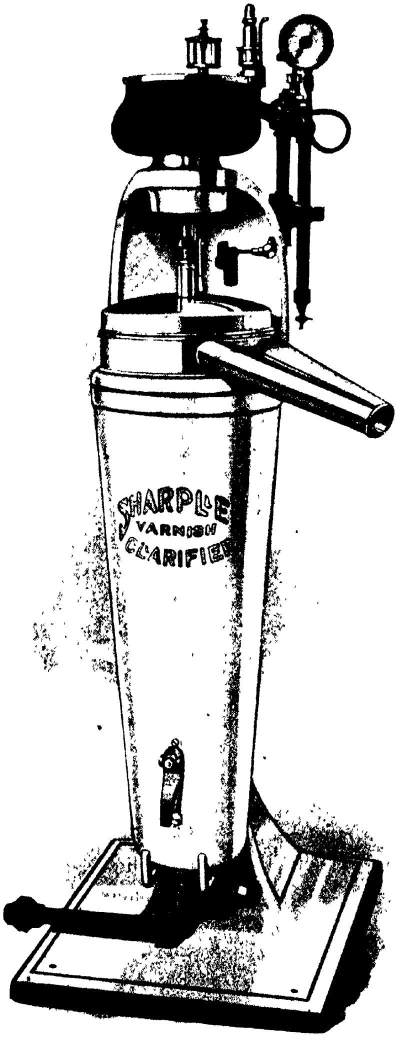


Fig. 90

Centrifugal clarification is a process of stratification by subsidence, the liquor passing through no obstructing medium. A gelatinous solid will usually separate with rather less difficulty because of its gelatinous nature in the centrifugal bowl although it will clog a filter.

The separator type of centrifuge is for the separation of mixtures or emulsions of immiscible liquids, the liquids being continuously and separately discharged (Figure 91). The machine is operated and the liquid is fed to it in the same manner as in the case of the clarifier but as two liquids are handled continuously, a bowl and discharge covers for the separate discharge of the two liquids are provided

The capacity of separators and clarifiers depends upon the nature of the problem. For instance, the separation of wool fat from waste scouring liquors is only 125 gallons per hour because of the presence of emulsifying agent soap and various impurities while the dehydration of crude petroleum is often as high as 600 gallons per hour.

Where there is more than 2 per cent of solids present the use of clarifiers or separators is not advised. For this work Bulk centrifuges are used which operate at low speed and are equipped with a rotor of large diameter, being thus similar to other bowl centrifuges.

The solid discharge Sharples Super-Centrifuge discharges both the liquid and solids continuously, but can be used only where it is not desired to save the solids. In order to accomplish continuous discharge there is introduced with the liquor to be treated a liquid immiscible with the primary liquid and of such specific gravity that both the primary liquid and the solids will float upon it. The heavier liquid thus acts as a continuous conveyor for the solids, which rests upon its inner surface, preventing them from lodging against the walls of the bowl, and finally discharging them with its own discharge. Such materials as amorphous wax from cylinder stock as handled in this manner.

To make a commercial separation of this type with the solid discharge machine, chilled brine is fed into the machine with the

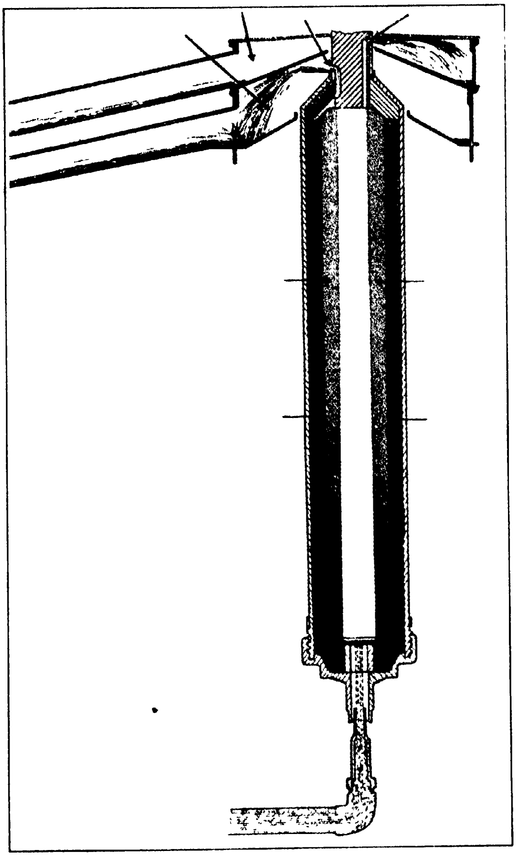


Fig. 91
The Process of Centrifugal Separation

chilled oil mixture. The brine being the heaviest constituent, forms a cylindrical column against the walls of the bowl. The oil mixture forms a cylindrical column within the brine column and the wax precipitating from the oil collects on the inner surface of the brine column. As the oil and brine travel up the bowl the wax, carried on the brine as a conveyor, passes up also. At the top of the bowl the brine and wax together pass outside of a baffle and discharge together from one set of ports into the lower cover, while the oil discharges inside of the baffle through another set of ports into the upper cover. The brine-wax mixture is collected in a sump and the brine siphoned from the bottom of the sump and recirculated through the machine.

This machine is so constructed that adjustments may be made to apply it to a wide variety of problems. It has, however, rather strict limitations for commercial use. It is essential that the carrier liquid must be immiscible with the primary liquid, otherwise they will simply combine on entering the machine and will not be separated by centrifugal force. It is also obvious that the carrier liquid must be of greater specific gravity than the primary liquid. Since there is no liquid heavier than water and immiscible with it that is sufficiently low in cost to make it useful in commercial work, it is, generally speaking, impracticable to discharge solids continuously if the primary liquid is water or a liquid miscible with water.

The second limitation concerns the solid suspended matter itself. It must be of such nature and specific gravity that, precipitating from the primary liquid, it will float upon the carrier liquid. It is frequently a fact that solids of greater specific gravity than the carrier liquid will float upon that liquid because they are wetted with the lighter immiscible primary liquid. For this reason it is usually possible to remove solids from oils with the continuous discharge of both the solids and the oils.

The Sharpes Super-Centrifuges are usually operated in batches of five or ten and require one man in attendance. They are admirably suited for some materials, notably those having a small amount of solids present, although they are intermittent as to operation, and take a good deal of power and labor.

Tolhurst Centrifugals.—A typical centrifugal machine, self-balancing centrifuge, nevertheless offers no difficulty in this retured by the Tolhurst Machine Works and illustrated in Figure 92. These machines are made in various sizes and rated accord-

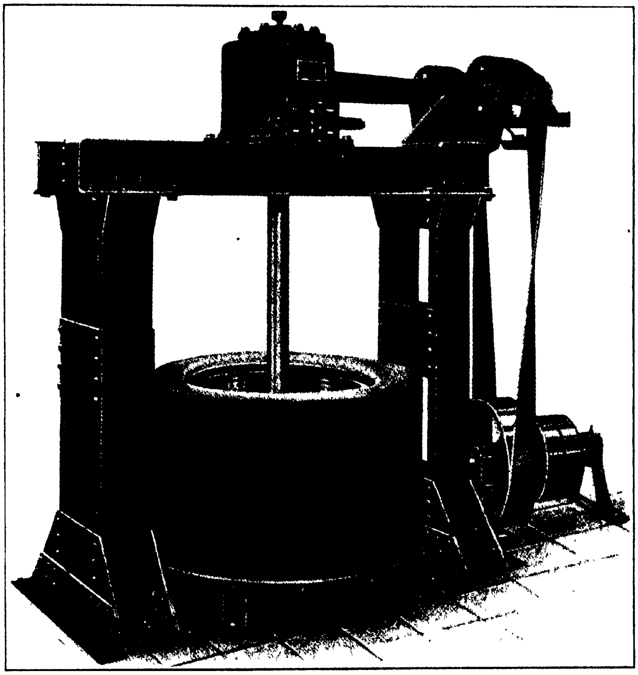


Fig. 92
Centrifugal

ing to the size of the basket; 26, 32, 40, 48, and 60 inches inside diameter. The construction is shown in Figure 93. The perforated basket "A" with a bottom discharge "B," the cone "C" valve which closes the large annular discharge opening in the bottom of the basket is shown lifted and held up by a hook on the post supporting the overhead driving mechanism. The outlet for liquor or filtrate is shown at "D."

In some industries unrestricted access to the interior of the centrifugal basket is essential and large open top under driven machines are required.

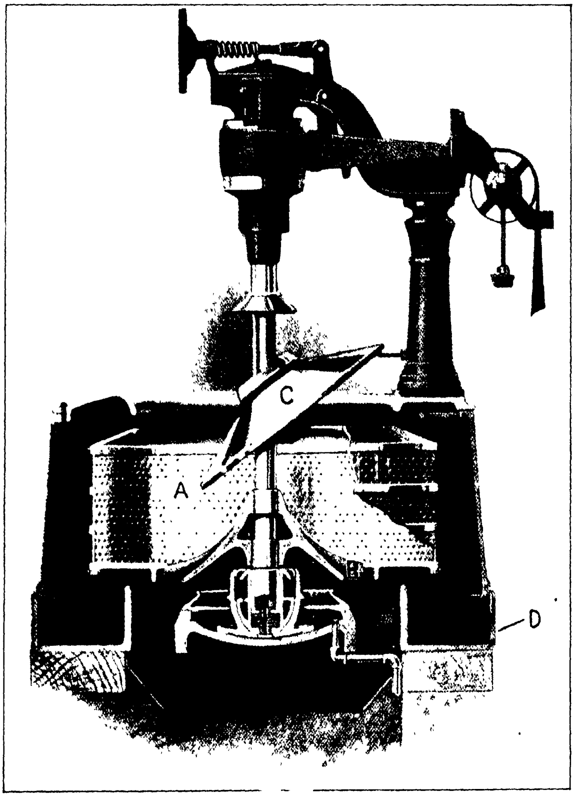


Fig. 93
Centrifugal Machine (Section)

This demand has been met with a center-slung centrifugal (Figure 94).

The safe and economical operation of a centrifugal is dependent upon its ability to accommodate itself to unbalanced loads and the center-slung machine, while radically different from the self-balancing centrifuge, nevertheless offers no difficulty in this respect.

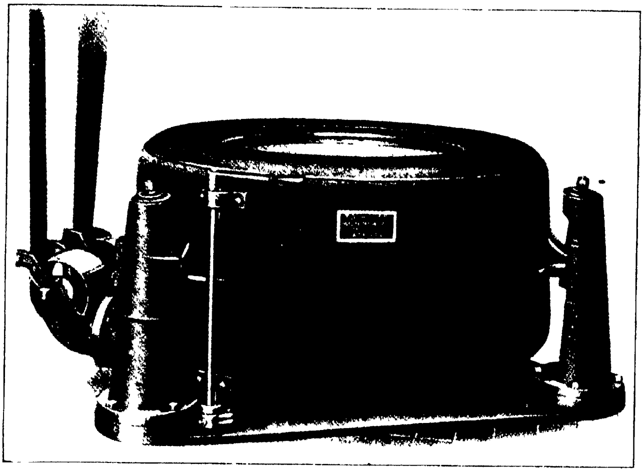


Fig. 91
Center Slung Centrifuge

The case, carrying the revolving basket, is flexibly slung by links from three short columns. The links are attached to the case at points about on a plane through the mid-depth of the basket. The resultant of the forces due to the unbalanced load and to gravity is such that the machine runs most smoothly and bearing stress and friction are minimized.

To further reduce friction and insure durability, three large sets of full roller bearings carry both the radial and direct thrust loads. These bearings are enclosed in a single dirt-proof housing packed with grease. This insures accurate bearing alignment, positive lubrication and eliminates troubles of oil leakage.

In handling materials of a highly corrosive nature it is often necessary to use a centrifugal with no bearings underneath the basket and which has a type of bottom discharge that will permit very rapid unloading. The suspended centrifugal (Figure 92) is entirely supported by heavy roller and ball bearings flexibly mounted in the driving head, providing positive control of the oscillation of the basket. The spindle or vertical shaft is of the solid spindle type and the bearings are lubricated with non-fluid grease and so arranged that the lubricant cannot enter the basket.

The discharge opening in the bottom of the basket is closed by a cone valve and the basket may be quickly unloaded after centrifuging. The baskets of these machines may be constructed of various materials and the cases lined with rubber, lead, etc., as desired.

The Tolhurst centrifugals are typical of this class of apparatus and as such give low moisture contents in the discharged cake, rapid drying and positive results, but of course are intermittent, require considerable power for driving and labor for cleaning.

CHAPTER VI

AIR, GAS AND LIGHT FILTERS

The filtration of air and gas is as a rule simply clarification, either to remove impurities or to conserve valuables, while the filtration of light is selective elimination.

Generally gas filtering apparatus and air cleaning systems are the same in construction and operation so that a discussion of the apparatus for these purposes can be taken up without distinction as to whether they are for air or gas. Air filters are used to purify air, either for use in turbine engines or other machines, or for drying purposes, or to free from impurities air which is to be used in workrooms or where machinery is operating. Gas filters have as their object the recovery of valuables which otherwise would be lost in the air, or the removal of dangerous or objectionable impurities from the gas. They are used in connection with blast furnaces, gas-houses, smelters, etc.

The old process and the one which is still used where other apparatus can not be afforded is the bag house collector. This consists of a series of bags like Taylor filters through which the exhaust gases are passed by means of pressure through a flue. The dust is collected inside the bags and is removed at intervals by hand. This system was formerly extensively used for the recovery of valuables, but has now been replaced in most of the large plants by the Cottrell System Manufacturers of dust collectors, of whom there are a great number, may roughly be divided into three classes; (1) those who separate by sedimentation; (2) those who separate by filtration and (3) those who employ electrical clarification by the Cottrell System. In the first class, use is made of baffles to create still-air pockets through which the dust particles settle by gravity. The passage of the air or gas is aided by a fan at the clean air or gas end, or the pressure of the rising air or gas may be enough to cause it to pass through the collecting system. Of this type the Clark Dust Collector, the By-Products Recoveries Collector, and the Sturtevant Dust Collector, are representative.

In separation by filtration, clarification is accomplished by passage through cloth screens or rotating coarse screen discs, suction usually being employed to draw or pressure to blow, the dust laden air or gas through the system. Typical machines of this type are Clenworth, Wheal & Co. Air Filters, the Norblo Suction Filters, the Sturtevant Vacuum Cleaners, and the Conkey Dust Collectors. There are of course also numerous air washers and air conditioners to remove dust, foreign material, and soluble impurities from the air. In general principle these washers and conditioners are all alike, the air passing through a spray chamber, which brings it in contact with a rain-like spray, is washed clean of impurities, is then passed over eliminator plates to remove the entrained moisture and finally is discharged into the desired place. The water for washing may be re-used and the air may be chilled by refrigerator coils or heated by steam coils where this is of importance.

Light filters are employed principally in scientific work or laboratory experiments Although the process is one of selective absorption by a medium, the result is the eliminating of certain light rays by the passage through a medium which affect is similar to that obtained by filtration.

By-Products Recoveries Dust Collectors.—The By-Products Recoveries Company makes dust collectors, particularly for cement mills, blast-furnaces, foundries, chemical plants, smelting works and grinding mills.

The apparatus called the Reverse Nozzle Dry Dust Collector, Figure 95, in which the By-Products Recoveries Company specializes, consists of a tight box through which the gases pass in a horizontal direction. The dust-catching section is built up of unit boxes, each of which is composed of a curved perforated front and back, two flat sides, and a tight central partition. The top is closed by the cover of the machine and the bottom rests on the floor grid over the dust bin. These boxes are narrow and short but extend from the top of the machine to the dust bin. When assembled in the machine they form numerous nozzle-shaped gas passages between the sides of adjacent boxes, the outlet of which discharges

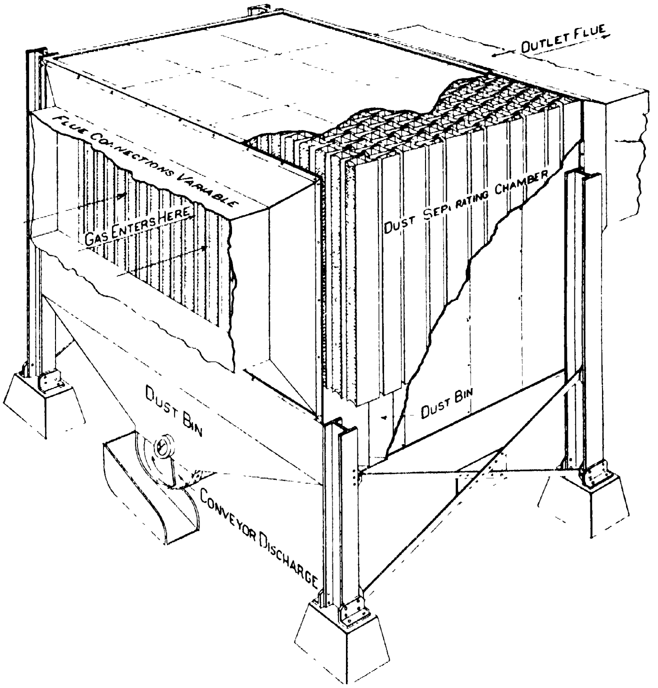


Fig. 95
By-Products Dust Collector

on the curved front of the following set of boxes. The dust bin is sectionalized by partitions which correspond with those in the center of the boxes to prevent the flow of gas through it. The dust is finally removed from the system by a conveyor or dumping doors and discharged into a convenient receptacle.

On entering the machine the gas is separated into numerous narrow vertical streams by the deflectors in the distributing chamber and these streams impinge on the curved perforated plates which form the front of the boxes. Behind these perforated plates are still air settling spaces formed by the two sides and the vertical partitions of the box. The top and bottom of the machine make these spaces tight still pockets of air which do not move with the gas stream. Thus a particle of dust thrown through the perforations either by direct impact or by centrifugal force, as the stream is rapidly reversed upon itself, passes out of the gas stream into the still air space and falls into the dust bin below. The perforations act as a screen to separate the dust from the gas and a particle of dust need only move a fraction of an inch to be through the screen into the still air space. The gas stream is deflected 180 degrees by the front plates around the curved surface until it has entirely reversed its direction and flowing in the opposite direction a short distance impinges on a similar plate forming the back of the box. In the rear of this perforated plate is still another still air space formed by the two sides and partition in the box. This acts in a similar manner to drop the dust into the dust bin. The back curved plate again deflects the gas 180

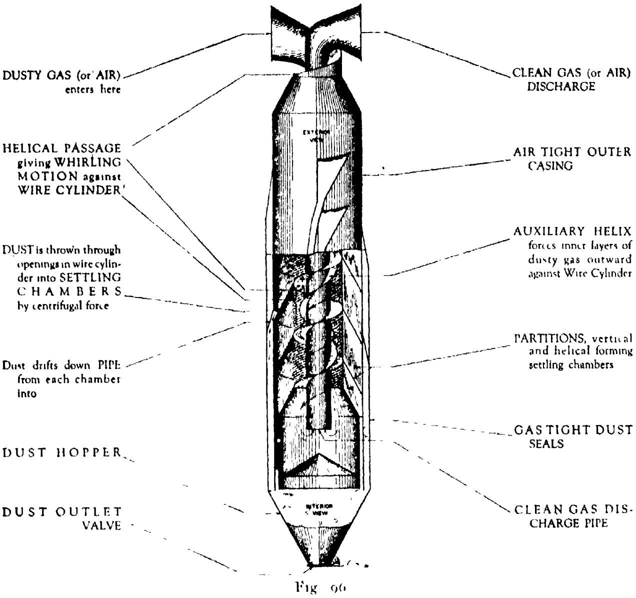

DUSTY GAS (or AIR) enters here
HELICAL PASSAGE giving WHIRLING MOTION against WIRE CYLINDER
DUST is thrown through openings in wire cylinder into SETTLING CHAMBERS by centrifugal force
Dust drifts down PIPE from each chamber into
DUST HOPPER
DUST OUTLET VALVE
CLEAN GAS (or AIR) DISCHARGE
AIR TIGHT OUTER CASING
AUXILIARY HELIX forces inner layers of dusty gas outward against Wire Cylinder
PARTITIONS, vertical and helical forming settling chambers
GAS TIGHT DUST SEALS
CLEAN GAS DISCHARGE PIPE

Fig 96
Taylor-Milliken Dust Collector

degrees back to the original direction, where it enters the passageway formed by the sides of the adjacent boxes, making a direct run until it comes in contact with the curved perforated plate of box (2), where the gas undergoes the same reversal and the process is repeated as often as there are boxes

The reserve nozzle dry dust collector is very positive in operation and by its numerous baffles and deflections insures a clean gas discharge. As it is solidly constructed and has no moving parts except the discharge conveyor there is practically no wear on the apparatus or danger of its getting out of order. The same action which insures a clean gas however, cuts down the rate of flow, adding thus to the power necessary to deliver a given capacity. There is also the objection that if the gas contains any moisture the dust will stick to the perforations and throughout the entire system, thereby clogging it, and the construction is such that cleaning to remove wet dust is extremely difficult.

The system while relatively new has been installed in a number of plants where the conditions were favorable and satisfactory results are being obtained.

The Taylor-Milliken Dry Dust Collector takes advantage of the fact that solid particles in suspension, however fine, may be separated from any gas by centrifugal action on the particle.

In this machine, Figure 96, the centrifugal force is applied to the dust particles by forcing the dusty gas to travel through a spiral passage at high velocity. The outer side of the passage consists of wires, separated to form narrow slots through which the dust particles are carried by centrifugal force into the settling chambers, where there is no general movement of the gas.

The settling chambers are formed by the outer air-tight casing of the machine, together with vertical and sloping helical partitions. The sectionalizing of the annular space between the outer casing and the wire cylinder by these partitions prevents the gas or dust from being carried back into the main gas stream.

In addition to the centrifugal force above mentioned, another means to further accelerate the separation of the dust from the gas is used. An auxiliary helix of steeper pitch than the main one, forces the layers of dust laden gas from the inner side of the stream outward against the wire screen, where the centrifugal force throws the dust through the slots into the settling chamber.

The machine also acts as a classifier of the dust, as the coarser particles will be most strongly affected by centrifugal force, pass through the gas first, and deposit in the upper settling chambers The centrifugal force on each particle at ordinary gas velocity used, is over one hundred times its weight. This forces the dust particles through the slots at high velocity, and for this reason, the wire slots do not fill up with the dust. When fume is present, it builds up on the wires until of sufficient mass to be thrown through the slots into the settling chambers. In some cases, however, the nature of the material makes it necessary to occasionally clean the slots.

High temperatures do not affect the operation of the machine as no inflammable material are used in its construction.

In case there is sufficient natural draft to draw the gases through the machine, no power will be required, as the machine itself has no moving parts. Where necessary, a volume blower may be used to supplement the draft.

Where gases or dust in suspension have a corrosive action on steel, the machine is constructed of non-corrosive materials, without interfering with its operation.

The design of the machine can be varied to meet a wide range of draft or flue velocities, and the installation of the machine is so arranged as not to interfere with existing conditions.

Clark Dust Collector.—The Clark Dust Collecting Company make dust collectors to minimize fire hazards, to prolong the life of belting and machinery, purify air for workers, and to recover by-products. This company makes a specialty of fire and explosion prevention, by the collection of dust in starch factories, bakeries, powdered coal plants, etc. In general it manufactures the Clark Rarified Dust Trap, the Clark Adjustable Air Separator, the Clark Chicago Collector and is agent for the Norblo Suction Filter.

The Clark Dust Collecting System of all-metal construction is shown in Figure 97, where "A" is the dust laden air inlet, "B" the Clark Adjustable Air Separator, "C" the coarse dust discharge, "D" the fan, "E" the Clark Chicago Collector, "F" the coarse dust discharge, and "G" the pure air discharge. The Clark Air Separator is used in classifying and grading any material suspended in the air and when part of collecting system it takes out the coarse particles and thus insures a longer life to the fan.

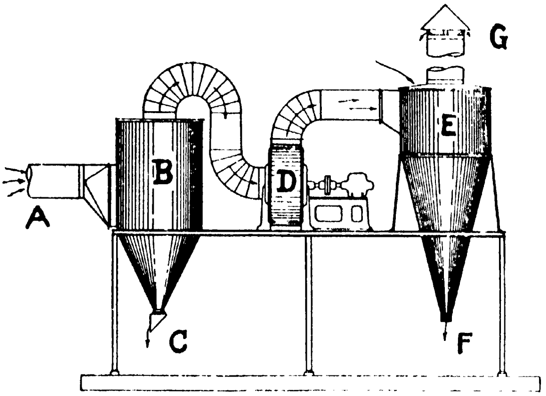


Fig 97
Clark Dust Collecting System

The Norblo Suction Filter, like the other separators, may be used as a single unit or battery of units or part of a system as shown in Figure 98. The cylinder of the filter contains twelve closely woven cloth bags which strain the dust laden air and there may be from two to any desired number of these cylinders in a filter. The air and dust are drawn into the bottom hopper of the cylinders, either directly or after passage through the adjustable air separator, and strained through the bags. The clean air passes out through the manifold at the top and thence to the fan while the dust is left on the outside of the bags. The dust is cleaned from the bags by automatically reversing the air current and applying air pressure through the valve in the outlet at the top of the filter.

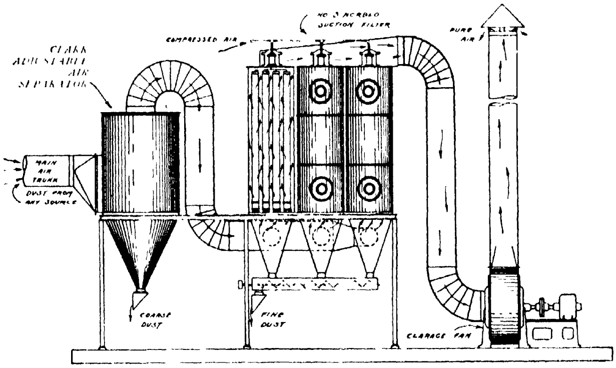


Fig 98
Dust Collecting System

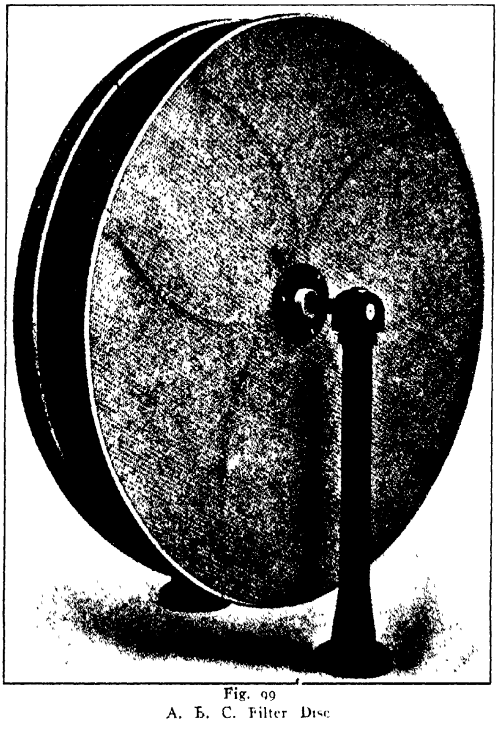


Fig. 99
A. B. C. Filter Disc

It is claimed for the suction filter that when handling injurious materials there is no danger of dust or gases escaping through a hole in the cloth and out into the room as the direction of flow is inward. The Clark dust collecting systems are used in powdered coal plants, metal smelting and refining works, crushing and grinding plants, cereal plants, chemical works, ash conveyors, milk drying plants, shoe factories, spinning mills, sand blast machines, etc. They are built in sizes capable of handling from 500 to 12,000 cubic feet of air per minute or in special sizes where required.

Clenworth, Wheal & Co. Air Filters.—The air filters made by Clenworth, Wheal & Company are usually divided by them into three classes; A. B. C. air filters which serve to remove impurities from the air and collect dust; Natural Humidifiers which not only remove the impurities but regulate the humidity and temperature of the air; and Desk Coolers which circulate, clean and cool the air, especially in tropical countries.

The A. B. C. air filter consists of a number of discs, Figure 99 usually 3 feet 4 inches to 10 feet in diameter, of small mesh expanded metal, Figure 100, spaced at suitable distances apart

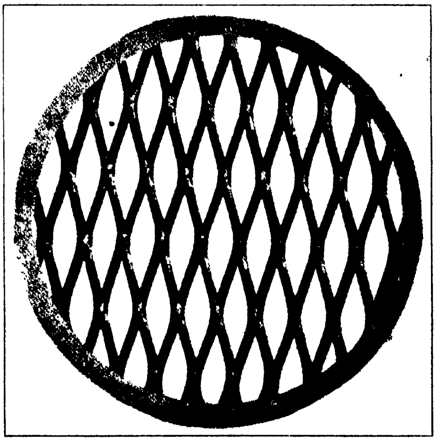


Fig 100
Expanded Metal Screen

and staggered to cause the air to zig-zag in its passage through the filter, thus scrubbing and cleaning it. The discs dip into the water in the lower part of the casing for a few inches only as shown in Figure 101. The discs are nested together to form a rotor and are built on spiders and enclosed in an outer metal rim, the whole making a rigid and substantial structure. This rim makes a running joint against a wood-lined baffle which prevents any unfiltered air from passing. As the rotors revolve they automatically pick up sufficient water to thoroughly wet and cleanse each of the discs and leave the solid impurities behind in the lower part of the casing. Hand holes are provided so that the dirt can be cleaned out periodically. Two or more rotors are provided and carried on and rotated by a shaft by means of totally enclosed gearing. This gearing can be operated by a direct-coupled motor or by a belt. Owing to the tortuous course that the air takes it is cleaned before it reaches the final stage of the

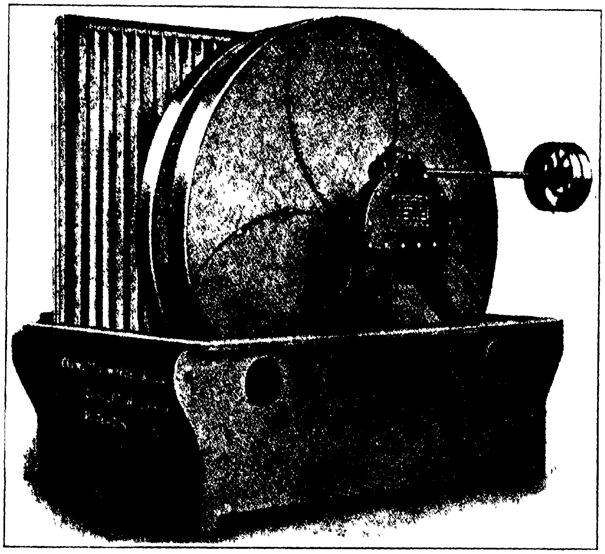


Fig 101
A. B C Air Filter

filtering rotors so that there is no danger of the hooks of the eliminator becoming choked with dirt. The eliminators are a separate unit, Figure 102, detachable and therefore can be taken to pieces easily for repainting, when need be.

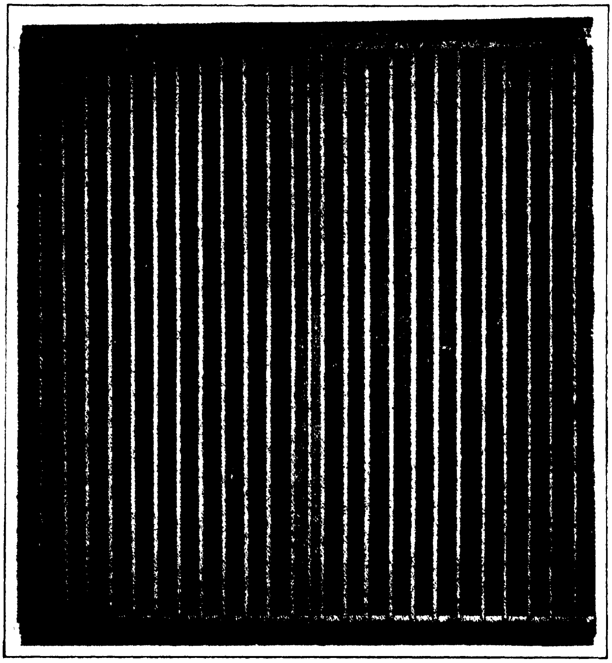
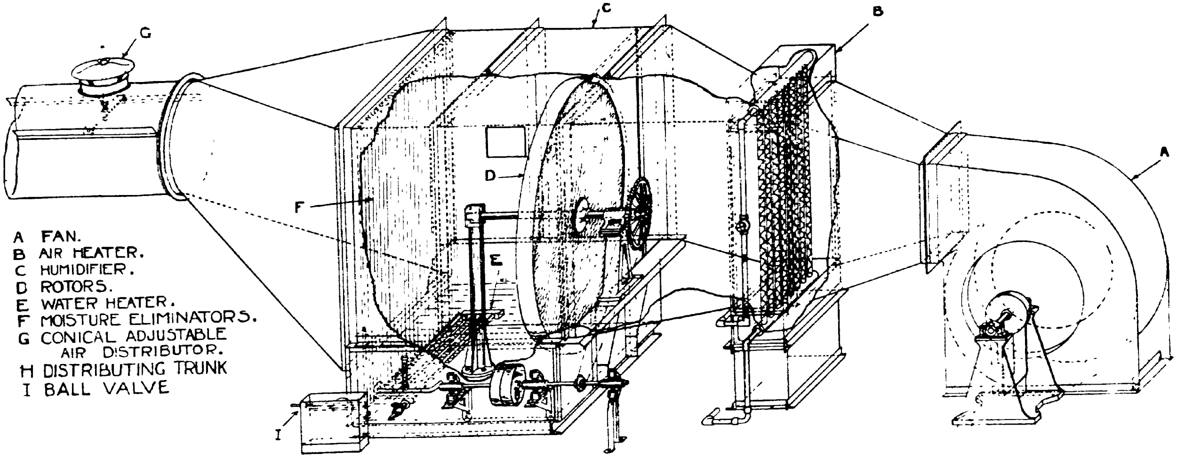


Fig. 102
Eliminator Unit

The apparatus is suitable for ventilation of every description particularly for the ventilation of turbo-alternators, as well as the collection of dust from all kinds of plants, where the gases are very hot it is, of course, necessary to cool them before passage through the filter. The capacity roughly ranges from 2,000 cubic feet per minute in a machine with three foot four inch discs to thirty four thousand cubic feet per minute in a machine with ten foot six inch discs, although capacities may be as high as

THE NATURAL HUMIDIFIER.



PICTORIAL VIEW OF HUMIDIFYING INSTALLATION

FOR CLEANSING TEMPERING AND HUMIDIFYING AIR

Fig 103

100,000 cubic feet per minute in special cases. The filtering surfaces may be made of steel, brass, copper or any specified material.

It is claimed for these filters that as the strands of the filtering surface are at an angle the resistance to the air passing through the filter is at a minimum, and the effective area for the air at a maximum, the rotors being immersed in the water for a few inches only, practically the entire area through the mesh is available and the resistance in the water gauge is very low. The filtering is arranged so that the vapor tension is not increased unduly and the insulation resistance of the generator is not lowered to any extent. Lubrication is so arranged that oil cannot get into the filter, little power is required for operation and there is no danger of loose moisture.

The Natural Humidifiers are used in textile operations to make the fibres of cotton, wool, silk, flax, etc., more pliable, to reduce the breakage of ends, to increase the strength of the yarn, to increase the length of cloth, to make cloth more uniform in width, to eliminate the generation of static electricity, to reduce dust, waste and fluss, by giving uniform humidity throughout the factory in all seasons and in all climates. Besides removing the dust and regulating the humidity the apparatus controls the temperature so that in winter the air may be heated and in summer cooled. Figure 103, illustrates very clearly the operation of this apparatus which is similar to the air filter already described. Where the filtration of the air is not of primary importance the expanded metal surfaces are kept stationary and a suitable means of distributing water over them used.

It is claimed for this machine in addition to the advantages mentioned under the air filter that: the temperature is maintained practically constant as is the humidity, there is no precipitation of free moisture, the air being conditioned at one central point and distributed to the room patchiness is eliminated, and the best working conditions for operators are produced.

The Desk Cooler, Figure 104, is placed in front of an ordinary electric fan which is so arranged that the air from the fan is projected on to the propeller of the desk cooler, thus supplying

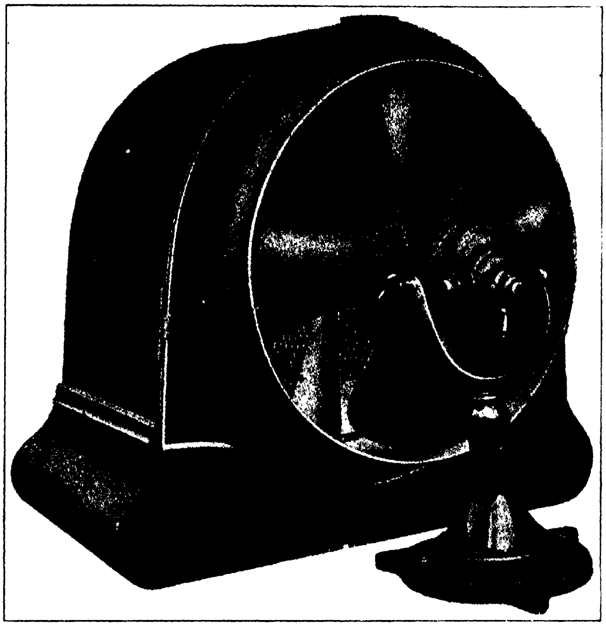


Fig 101
Desk Cooler

the necessary power to rotate the rotor. The desk cooler consists of a central spindle which, pivoted at either end upon adjustable bearings, carries the rotor and propeller. The rotor is made up of four discs of expanded aluminum spaced at suitable intervals along the axis and enclosed in an outer rim of aluminum. The discs are firmly fixed together The propeller is designed to give the necessary rotation to the rotor and at the same time to restrict the passage of air as little as possible. The whole is enclosed in a casing which contains water, as in the air filter.

The machine produces cool, clean air, requires no attention and it is only necessary to keep the water tank filled with water and switch on the fan when operation is desired.

Sturtevant Apparatus.—The B. F. Sturtevant Company make air washers, dust collectors, and vacuum cleaners among their other products. The air washers do not differ from the general description given on Page 122 and illustrated in Figure 105. They are of importance where air is to be used for drying, as in laundries, paint shops, photographic supply factories, etc., or where the dust is explosive as in rubber factories and sugar refineries, or for removing obnoxious odors from stock yards and coal tar plants, or for humidifying the air for public buildings, textile mills, and tobacco factories or for cooling the air in theatres and hotels.

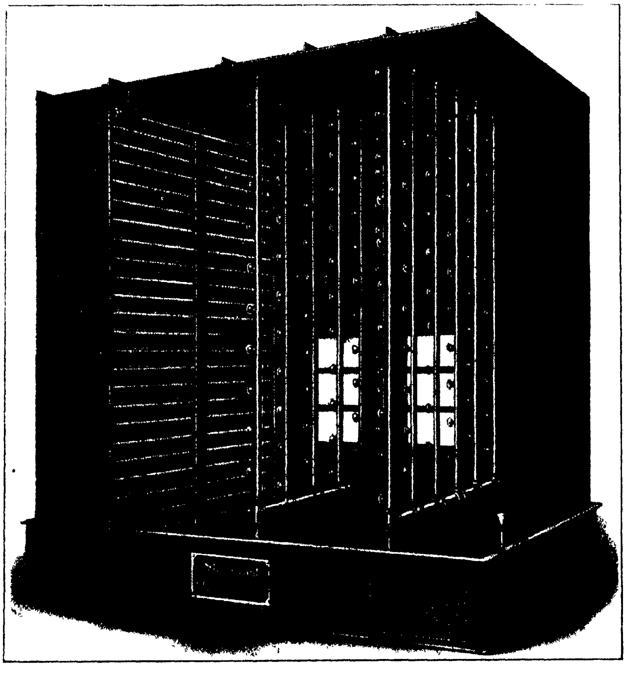


Fig 105
Air Washer

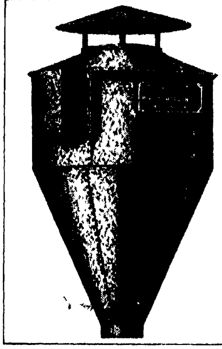


Fig 106
Dust Collector

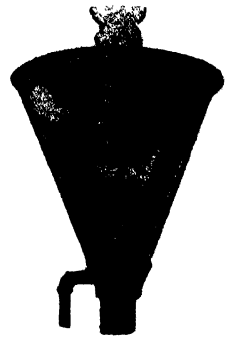


Fig 107
Oil Separator

Dust collectors of the Sturtevant type simply deflect the passage of air to allow the solid particles to drop out (Figure 106). The collector is used in planing mills, in buffing and polishing plants, tanneries, kitchens, schools, mills, etc., or in a little different style for separating mingled oil and moisture from exhaust steam (Figure 107). Since water weighs 1,600 times as much as an equal volume of steam a whirling action throughout the steam causes separation by centrifugal force, as taken up with the Anderson Steam and Oil Separator in Chapter VIII. Everyone is familiar with vacuum cleaners so they need not be gone into except to state that they are a direct filtration application. The dust is filtered out through several layers of unbleached muslin or other cloth screen by means of suction and this is the same principle which has been applied to bag-house collectors and other dust filtering machines.

The above mentioned types of apparatus, whether air washers, dust collector or vacuum cleaners, are all positive in operation, and with the exception of the last have no moving parts, require no attention to speak of, and little power for operation.

Zenith Dust Collector.—The Industrial Filtration Corporation manufacture a dust collector for the handling of either wet or dry dust. In this respect it differs from the other suction dust filters described (the A. B. C. air filter being the only other machine capable of handling wet dust) as well as by the fact that filtration is through but a single layer of cloth and cleaning is automatic and continuous

The general design of the machine is illustrated in Figure 108, and it will be seen that the apparatus is very similar to the

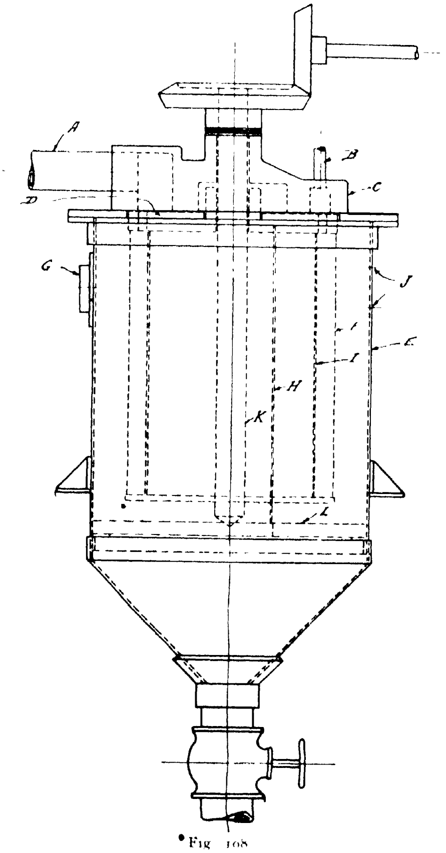


Fig. 108
Zenith Dust Collector

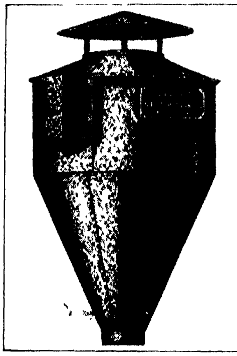
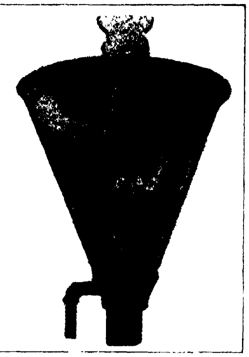


Fig. 106
Dust Collector



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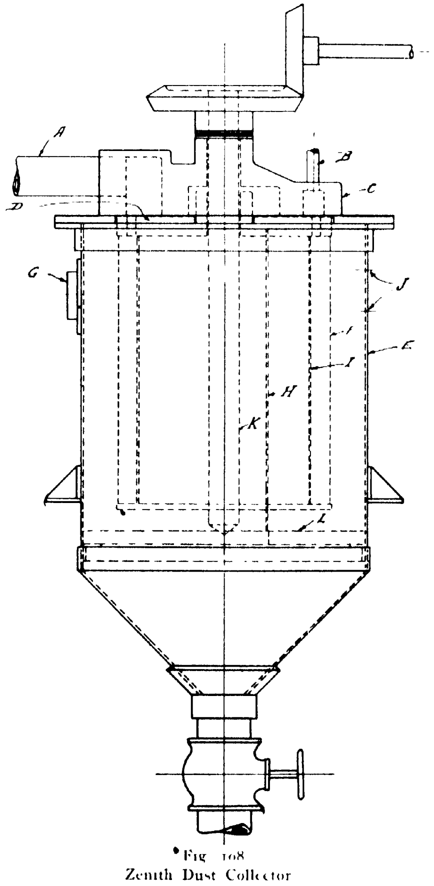


Fig 108
Zenith Dust Collector

multiple compartment rotary filter except that it is enclosed and can be operated by suction or pressure. The filter cylinder is divided into twenty or more compartments and is hung enclosed in a pressure outer cylinder. The inner or filtering cylinder is revolved during operation so that as each compartment in turn comes into the "dead" chamber it is automatically subjected to backwashing and tangent spray jets. The "dead" chamber is partially shut off from the main chamber by baffles and as there is no escape at the top or bottom there is little or no swirling of the gas or air.

The advantage of this machine is that it will handle saturated gases and automatically clean itself, therefore, its field of application is wide, the cost of operation is low as it is automatic and the apparatus requires no attention.

Cottrell System.—Although the Cottrell System may be considered filtration only in the broadest interpretation of the term, nevertheless it is of such importance in dust collecting and has to such a large extent replaced other systems that any discussion of air or gas clarification would be incomplete without a brief description of this type of apparatus.

In the Cottrell system the air or gases to be clarified are made to pass through metallic tubes in which charged wires are suspended. A low current is used, but the voltage is very high. These solid or dust particles pass between two electric terminals and upon entering the magnetic field are electrified with the same kind of a charge as one of the terminals and consequently are strongly repelled by it. The particles fall, on being repelled, to a collecting chamber and the air or gas passes out clean.

The system is largely used by smelters, refineries, and blast-furnace plants for the recovery of valuables or by acid companies, etc., to remove objectionable fumes. The operation is automatic and the results are positive clean air or gas always being obtained. The only objection to the apparatus is one of cost for small plants or where electric power is very expensive.

Light Filters.—Light filters as previously mentioned are filters in effect rather than in actuality. The colorimeter is one of the most important of this type and is used to measure the color intensity of liquids by transmitted light and the intensity of solids by reflection at different angles of incidence. As the pinion and operating heads are always in a fixed location, the observer's readings are controlled by observation only. The construction of the colorimeter evolves refinements such as tube bottoms optically inactive, plungers made from glass optically tested for color and in proper form, adjustments of microscopic precision, and enclosed housing for the prism system which is fixed, although the entire housing may be removed when it becomes necessary to clean the prism surface exposed. The scales read to 0.1 mm. by verniers.

The flame-color screen is another light filter of importance. It usually consists of a rectangular strip of mica divided lengthwise into three colors, (1) purple, (2) blue, and (3) green. The yellow flame color of sodium is absorbed by the screen, other flame colors appear as follows; potassium is blue-violet through (1), violet grading into reddish through (3), fainter and redder through (2), calcium (in volatile salts) gives a flash of greenish-yellow through (1), of green through (2), of faint crimson through (3), strontium and lithium are crimson through (3), and absorbed by (1) and (2), barium is green through (1), fainter green through (2) and (3), copper (chloride) is bright green through (1), bright blue fringed with green through (3), the same paler through (2), phosphoric acid is green through (1); light violet-red through (3). The screen in use is held close to the eyes and against a dark background and is very useful for determination of the presence of the above mentioned materials but of course will not give quantitative results.

There are a great number and variety of glasses and glass products from the spectroscope to sunglasses which absorbed, break up, or reduce the intensity of rays of light by partial absorption, which might be mentioned but the two foregoing apparatuses will serve as well as any to illustrate the general field of light filters.

CHAPTER VII

HYDRAULIC PRESSES

In hydraulic press work very high pressures are employed to affect the separation of the solids from the liquids.

In consequence of this especially strong substantial construction is required particularly in the pressure creating mechanism. In the majority of presses the feed is in batch lots, by hand, as is the discharge. This increases the cost of operation considerably but on the other hand very high percentages of extraction are obtained and the class of materials handled are as a rule those which could not be treated in any other way.

Hydraulic presses may be divided into the following: plate presses, box presses, cage presses, pot presses, and curb presses. Numerous other classes of hydraulic presses are made but as their work is not related to filtration they will not be considered here.

Plate Presses.—In the plate press class the three main types will be taken up: first the screw type, second the knuckle joint type and third the hydraulic press proper. The use of these types depends upon the material to be treated and the amount of output desired.

The screw press with steel beam and combination platform is shown in Figure 109. The press is designed for heavy and continuous work and is operated by the mechanism on the top with the pressure downward.

The second type or knuckle joint press is illustrated in Figure 110. The right and left hand screw produces a power almost unlimited when the levers are near the perpendicular, and the motion of the follower rapid at first when the material is soft, decreases in speed and increases the power as the levers straighten out, and the material becomes dense. The machine is especially adapted for the making of cider, and other beverages. The knuckle-joint press here illustrated has a reversible platform so that one pile of cakes (called "cheese") can be pressing while another is being prepared for the press. Presses of this type are also made hand operated for use in small plants.

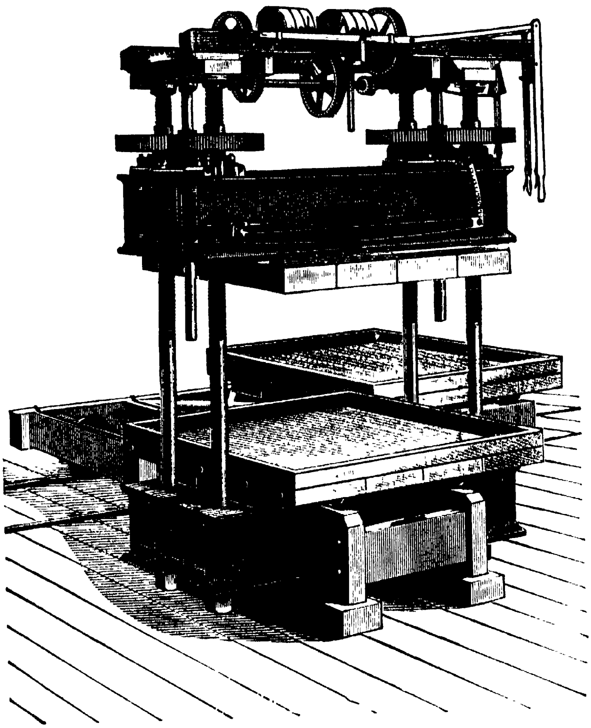


Fig. 100
Screw Press

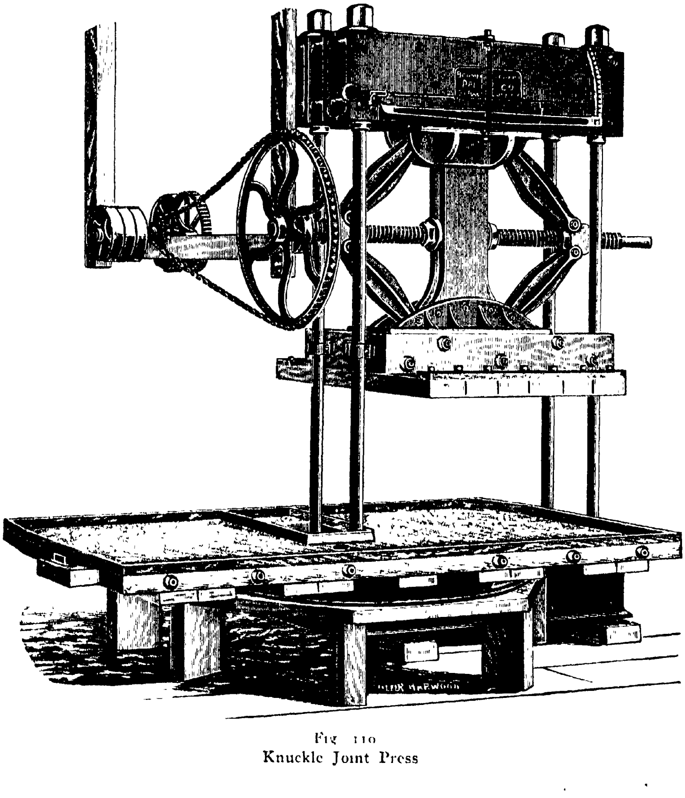


Fig. 110
Knuckle Joint Press

The regular hydraulic plate press is generally designed for heavy work and constructed with a view of giving great pressure and great durability as well. In Figures 111 and 112 are shown

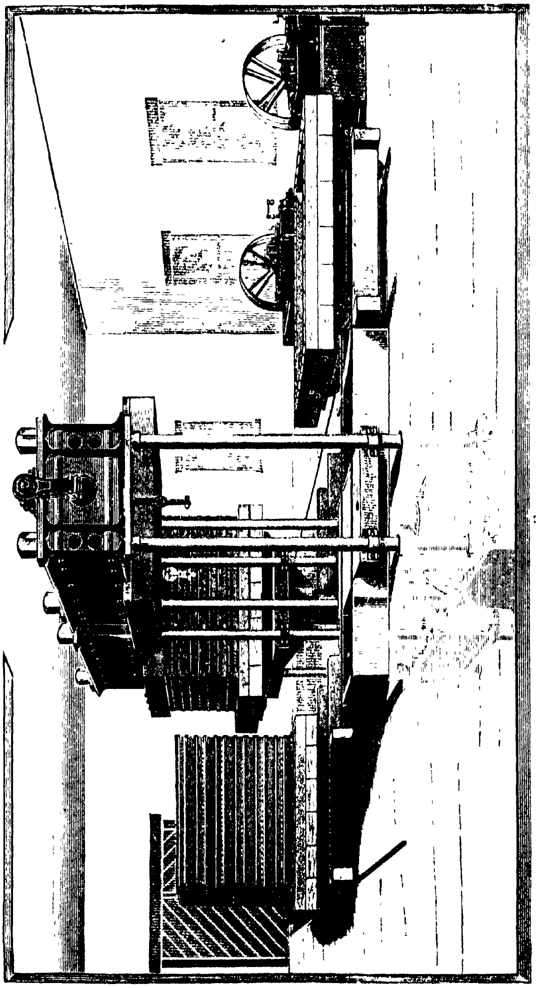


Fig 111

Hydraulic Press (Upward Pressure)

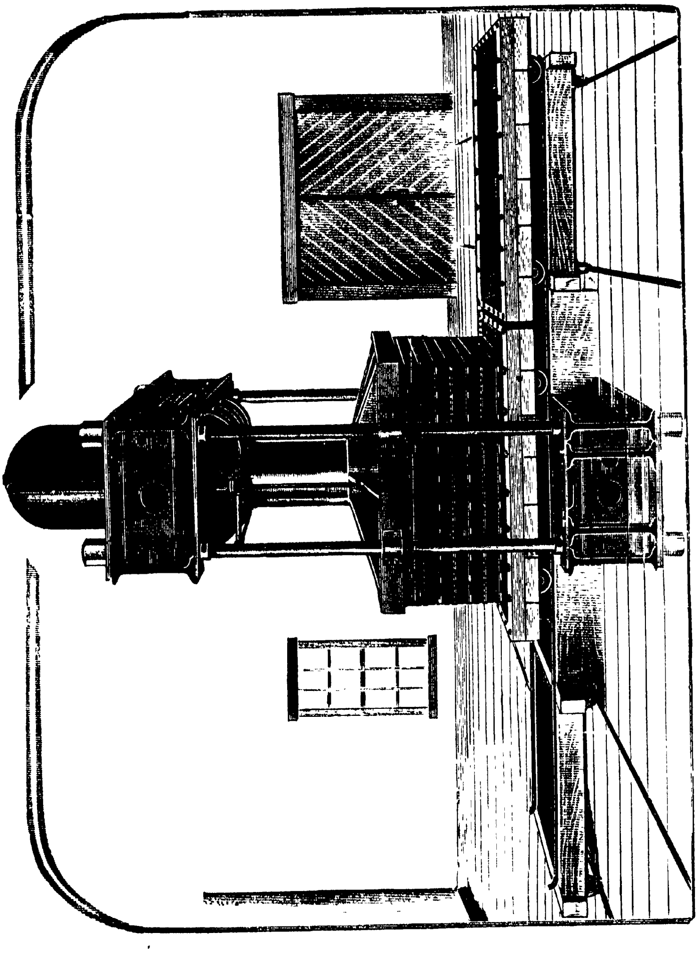


Fig. 112
Hydraulic Press (Downward Pressure)

the upward and the downward pressure types respectively. In both these the cylinder (a) is made of steel, the ram (b) is of cast iron turned and polished, the platen (c) is a heavy iron casting extending to and babbitted around the rods (d). The racks and material to be filtered are shown at (e) between the head (f) and the platform (g). Both have transfer car systems.

Racks are made square of wooden strips about one-half of an inch thick by one and three-eighth of an inch wide, placed about one-fourth of an inch apart, with strips 2 inches apart and three-eighth of an inch thick, nailed across, as shown in Figure 113. Double racks are also used as shown in Figure 114 with the same number of slats both ways. Although they are more difficult to clean and somewhat heavier they are very strong and durable.

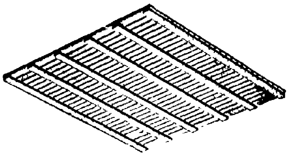


Fig. 113
Rack

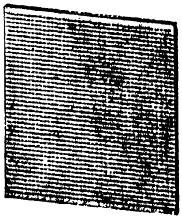


Fig 114
Double Rack

The form that is used to build up the cake is square inside and 3½ inches deep. It is made of boards 1 inch thick and 3½ inches wide. A board is nailed across each end and a casting is bolted in each corner in order to stiffen the form.

When it is desired to "lay up a cheese" (Figure 115), that is build up the layers of materials to be filtered, the operation is commenced on the platform of the press, a rack being laid down and the form placed on the rack. The form is 5 or 6 inches smaller each way than the rack. Over this form a cloth is spread and the form is filled full of the material to be pressed. The corners should be well filled and the center not rounded up. The corners of the cloth are now folded over the material, not too tightly, and the form raised, another rack placed in position, the form lowered, etc., until the "cheese is laid up."

The building of such a cheese is shown in Figure 115 When the last layer is formed, the form is taken off and a rack put on.

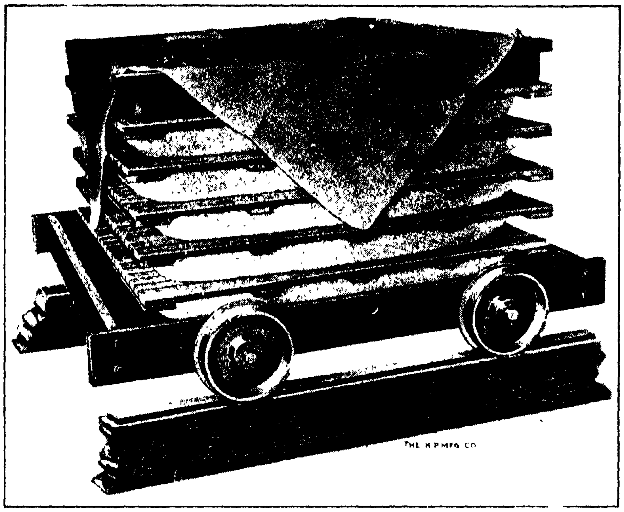


Fig 115
Building "Cheese" for Hydraulic Press

The follower is then placed in position and the pressing commenced. The liquid flows into the platform and is conveyed to tanks or other destination as desired.

The Worthington Press.—A special hydraulic plate press made by the Worthington Pump and Machinery Corp. works under three different pressures, gravity, pressure by weight of press descending under its own weight, and by hydraulic pressure. When the material to be pressed is first admitted, the free liquids flow off by gravity, or the material may be admitted under pressure, forcing the liquids through the bags in this manner. After the bags have become full of solids, the press descends slowly of its own weight, gradually forcing the platens together and squeezing the bags together, forcing out additional liquids. When this operation is completed, hydraulic pressure is applied to the cylinders and the platens forced together by means of the toggle joint arm, and normal pressure is applied to the cake in the bag to remove the balance of the moisture. A very dry cake is thus obtained.

During the final operation undue pressure does not build up at the ends of the bag for the reason that during the first stage of pressing the material is in a liquid state and the pressure is, therefore, approximately equal in all directions. During the final hydraulic squeezing, however, the material in the bag is in the form of a solid cake and the pressure is, therefore, normal to the

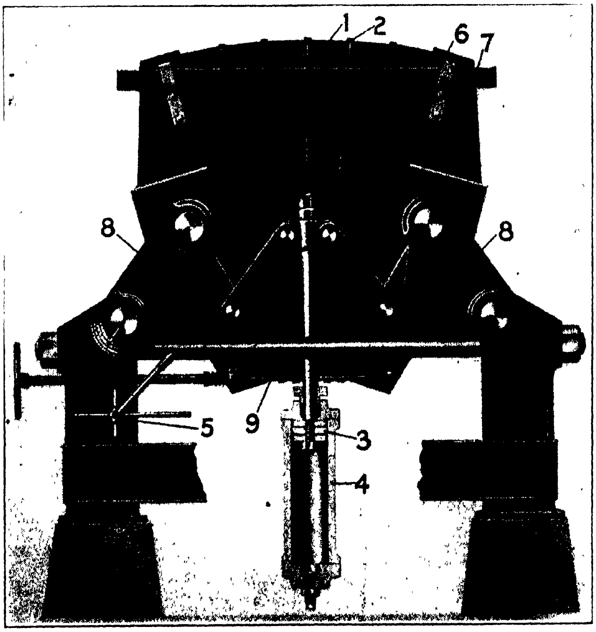


Fig. 116
Worthington Filter—Filling

platen faces and very little pressure is applied to the ends of the bag.

The Worthington press as illustrated in Figures 116, 117, and 118 has two vertical platens (6) pivoted at the centers to bell cranks, which are supported at their centers by shafts mounted in suitable bearings. The ends of each of the bell cranks are connected through suitable links and piston rods to a hydraulic cylinder. The side thrust of the bearings is taken up by means of the rods at each end. The bearings, which support the weight of the mechanism, rest on suitable concrete foundations.

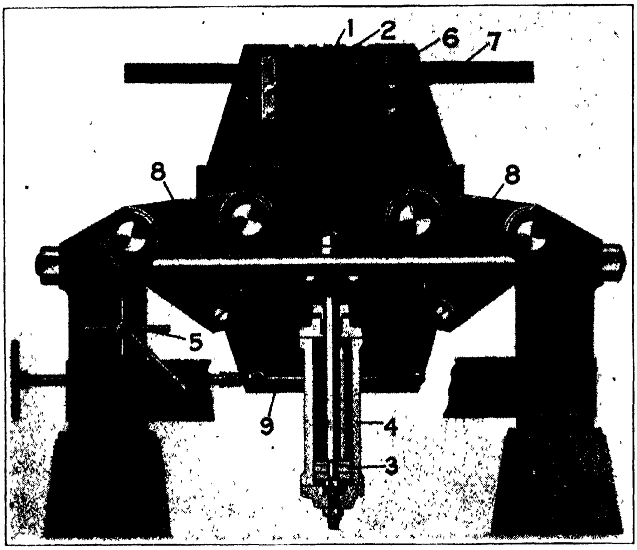


Fig. 117
Worthington Filter—Pressing

When hydraulic pressure is admitted to one side of the cylinder, (4) the platen pivots travel in the arc of a circle about the main bearing as a center, thus raising and opening the space between the platens, which are then in the form of a V, as shown in Figure 116.

A number of racks (2) of suitable material and construction are suspended between the platens and between each two of these racks is suspended a bag (1) made of a material suitable for the substance which is to be filtered.

Hydraulic pressure is gradually applied to the opposite side of the cylinder by means of a four-way valve, causing the platens

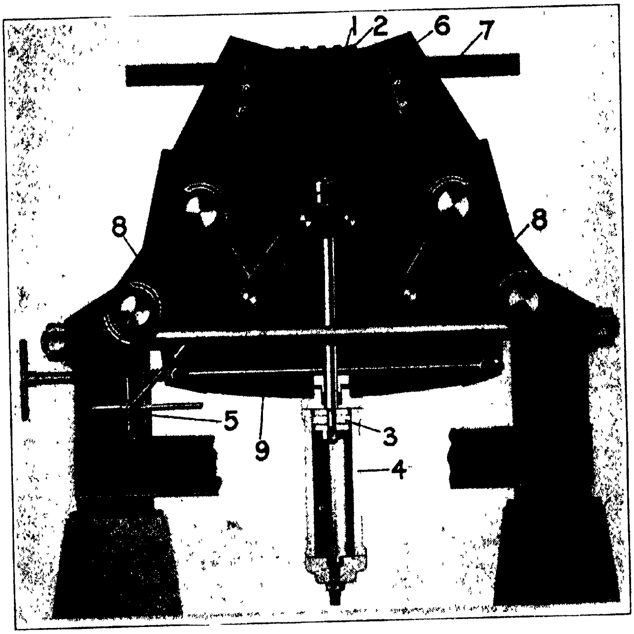


Fig 118
Worthington Filter—Dumping

to descend slowly. The speed of the descent is controlled by means of an adjusting valve located in the drain line.

After the descent of the platens, hydraulic pressure is again admitted to the same end of the cylinder as originally applied and the platens are raised to their former position, but are now in the position of an inverted V as shown in Figure 118.

The platens (Figure 119) consist of a cast-iron box section fitted with riveted steel plate facing, to take the tension on the inside surface of the platen and a similar steel plate backing to take the compression on the outside surface of the platen. Securely bolted to each side of the platens are two large steel pivots

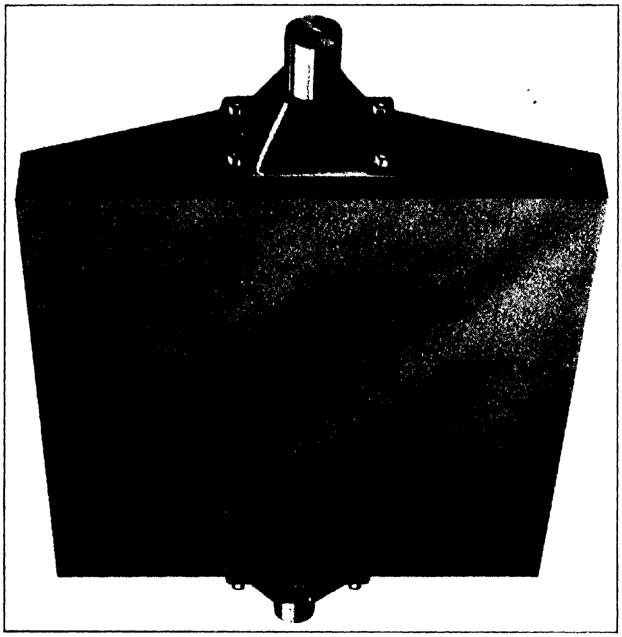


Fig. 119
Platen

carrying steel journals. These journals support the weight of the platen and are attached to the inboard ends of the crank arms.

Bags and racks naturally vary for the different classes of work. For material containing a very small percentage of solids it is necessary to use filter cloth bags, but where larger percentages of solids are to be handled, metal bags are used. The metal bag

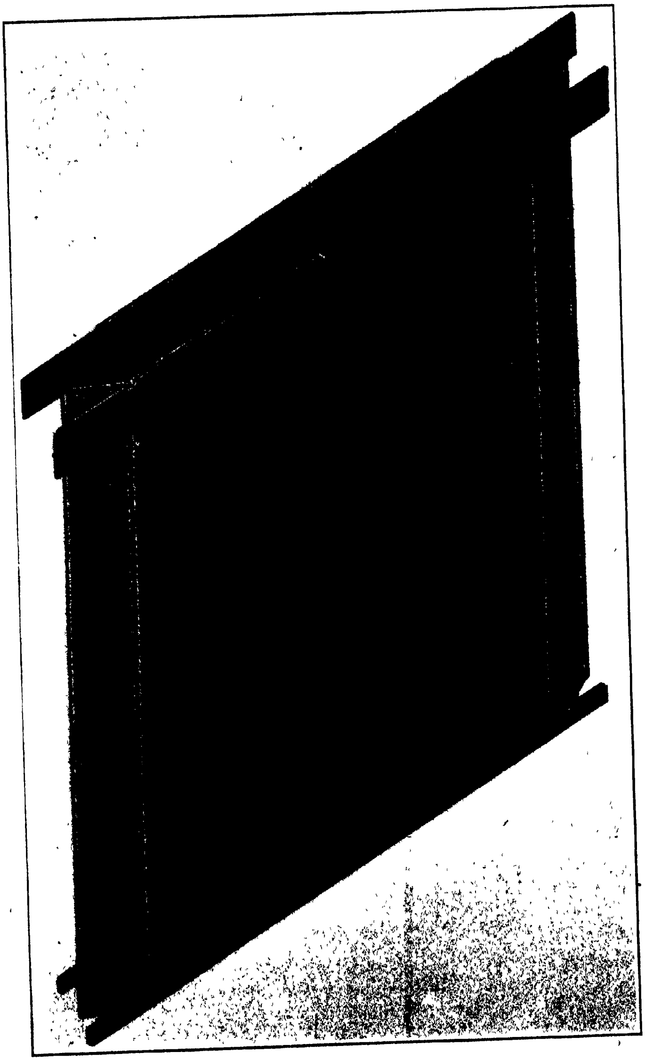


Fig. 120
Metal Bag

(Figure 120) is hinged at the sides and perforated with holes of suitable size for the material being handled. This type of bag has been used successfully on blood, and hog and beef tankage.

Corrugated racks (Figure 121) are placed between the bags and are so constructed that the corrugations run vertically, giving free drainage to the bags. A heavy sheet of steel plate forms the backing for the corrugated metal and effectually prevents buckling or distortion under the high pressure used. Where metal bags are used, the corrugations are on either side of the backing plate, and where cloth bags are used, the backing plates are on either side of the corrugations. When it becomes necessary to use a large number of bags and racks, the racks are fitted with rollers at the ends to allow free motion of the racks on the I-beam support bar.

The shafts, tie rods, cranks, cylinders, pistons, bearings, etc., are made of steel and iron as the case may require.

A complete cycle of the press comprises three steps, namely: Filling, pressing and discharging. Figure 116 shows the press open to take the material. Figure 117 shows the position of the platens when near the final pressing operation. The great power of the toggle joint is now being brought into use. Figure 118 shows the position of the platens when discharging.

During the filling operation the material is dumped into the press by some suitable means and gradually fills up the bags (1), which are held between the platens (6) by the rack bar (7), draining out through the perforated sides of the bags, down through the corrugated racks (2) to the bottom of the press, from which it is carried away by some suitable means. During this operation the press acts as a gravity press, the liquids passing off by gravity and the solids remaining in the bag. The press is held in its open position by hydraulic pressure admitted below piston (3) which holds it against the upper stays of the cylinder (4).

The press having been filled, the operating valve (5) is reversed to the downward position and the control valve is adjusted

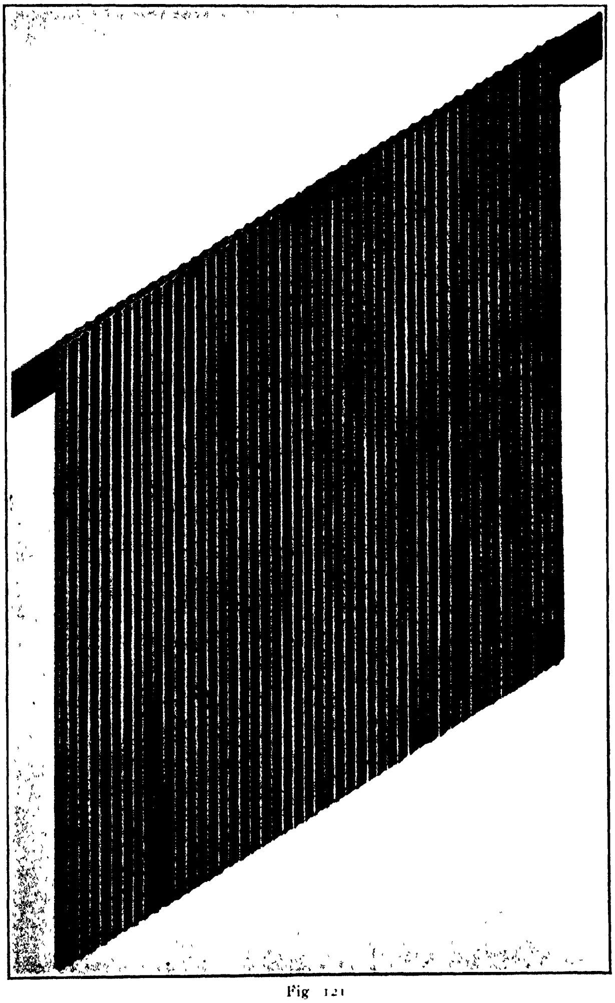


Fig. 121
Corrugated Rack

to regulate the closing or downward speed of the platens. This may be varied from a few seconds to several hours, depending upon the material handled. The platens now descend of their own weight, gradually exerting pressure on the sides of the bags. The liquids are further squeezed out of the bags until it becomes necessary to admit hydraulic pressure above the piston (3). This pulls the platens closer together and builds up the pressure rapidly by means of the toggle joint formed by the crank arms (8). The cake which, has formed already, is thus subjected to a final squeeze under enormous pressure, which relieves it of final free liquid content.

The press has now completed its pressing stroke and is ready for discharging. Hydraulic pressure is admitted below the piston (3) and the bags, which have been sealed at the bottom by the seal rods (9), now open, as shown by Figure 118, and the cake formed during the pressing stroke drops down onto a conveyor car, or other suitable apparatus, and is carried away.

Some of the uses of the press are for sugar factories, both cane and beet, packing houses, for edible and inedible beef and hog tankage, oleomargarine, blood, etc.; mining industries for the treatment of slimes and sewage and sludge disposal plants to some extent.

The claims made for this hydraulic press are: (a) simplicity in operation, (b) the press can be handled by unskilled labor, (c) the platens come together very rapidly during the first part of the pressure stroke and slowly during the last part, thus giving rapid filtration and reduction of volume when the material is liquid and vice versa when the material becomes more solid, (d) cakes are delivered very dry, (e) the press is easily filled and discharged.

Some disadvantages are that (a) in order to get a clear filtrate the platens must be nicely regulated in their descent, (b) bags are apt to burst if the speed is not regulated carefully, (c) the installation and maintenance cost is high.

Another press of this type is the hydraulic olive oil press shown in Figure 124. The expressing of oil from olives requires high pressure and a very strong and rigid press.

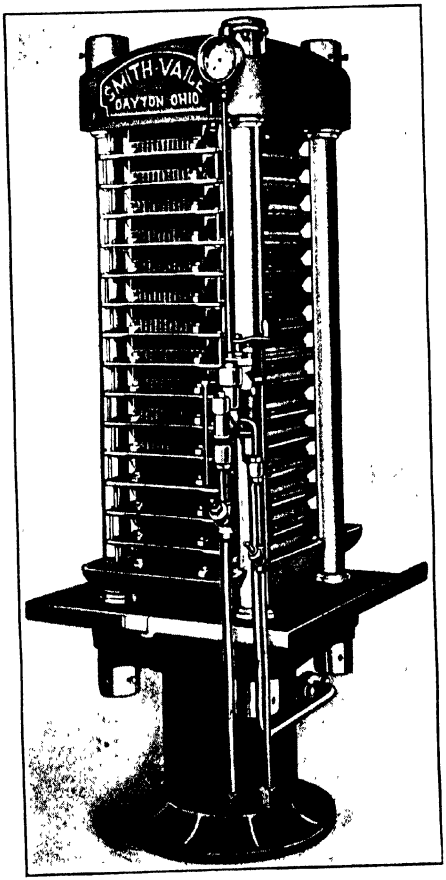


Fig. 122
Box Press

The crushed olives are placed in layers forming a cheese on a steel truck which is run into the press to receive the pressure. Each layer is wrapped in a special woven cloth made for the purpose, with steel plates between. This retains the solids and permits the oil to flow out. In the main, construction and operation are the same as previously described.

Box Presses.—The box press used to a large extent in cotton seed oil manufacture is illustrated in Figure 122. The press is fitted with fifteen built up all-steel boxes. The platen or ram block, is of semi-steel, the cylinder of cast steel, and the ram, 16 inches in diameter, is made of semi-steel.

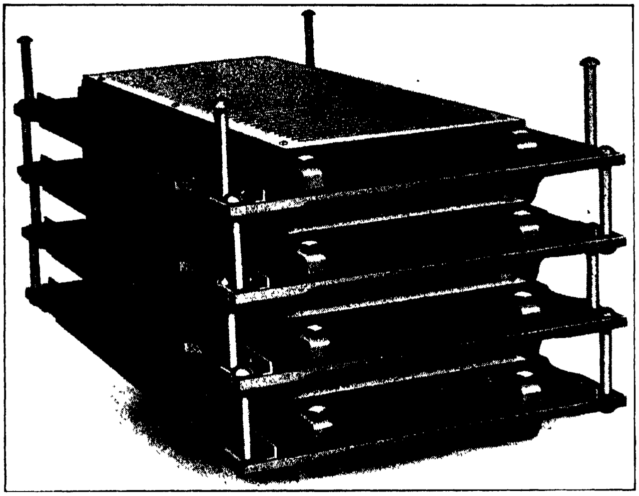


Fig 123
Steel Press Boxes

The drainage of the press is affected by setting the press with a slight backward inclination from the vertical. Heavy floor pans are provided for the purpose of conducting the drippings from the boxes to the drain trough in the rear of the press.

In Figure 123 are shown the steel press boxes. The side walls of the boxes are of heavy steel and the body plate is of five-eighth of an inch steel. Drainage angles are placed on the sides so all the liquid drains out.

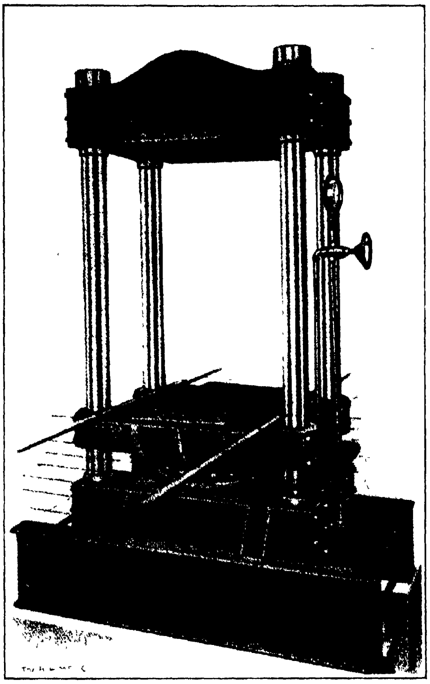


Fig. 124
Hydraulic Olive Oil Press

The underside of the body plate and the top of the steel mat is corrugated to prevent the slipping and creeping of the cake and consequent injury to the press cloth.

Cage Presses.—The cage press is one in which a very high hydraulic pressure is exerted against the material confined in a cylindrical cage, as shown in Figure 125. The operation is by hand and all the hydraulic part of the press is self-contained. The presses are supplied with filter plates so no filter cloth is required.

The method of operation may be seen from Figure 125. The sliding base with the cage is slid forward to the filling position by the operator, several layers of the meal, or pulp, to be

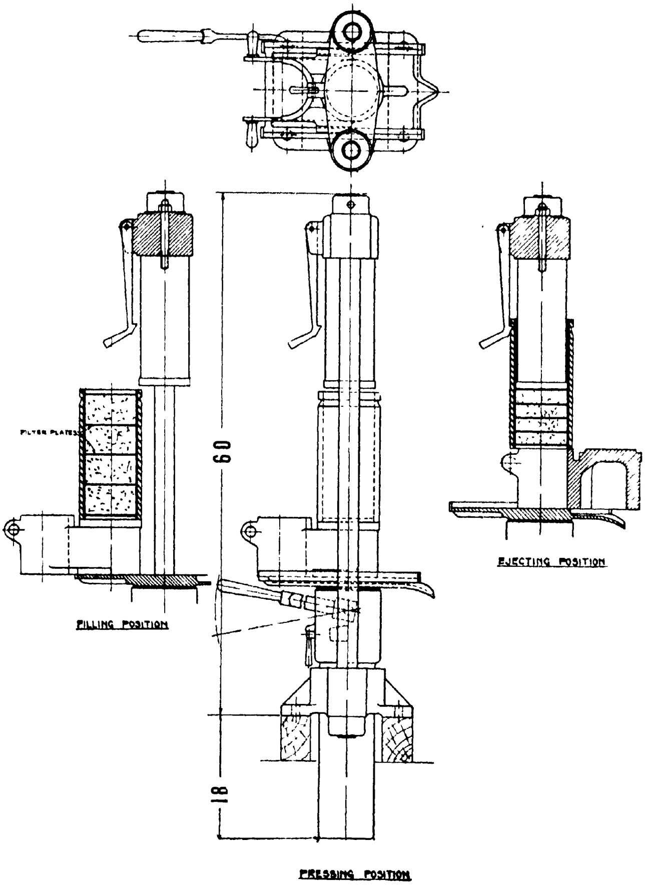


Fig. 125
Cage Press

pressed are put into the cage, with the filter plates dropped in between as indicated. The cage and its base are then slid into the pressing position. The operator, by means of the lever, pumps the press up until the plunger, descending into the cage, squeezes the material; this compresses it, forcing out some of the oil, making room so that more layers of meal may be added. As he pumps the press up again against the full compressed charge, the oil in the material is forced through the filter plates and edgewise out through the centers of them to grooves in the side of the cage, thence out into the catch pan of the press. Then the operator turns a lever which releases the pressure and lets the press back down of its own weight. As it descends, the cage with the pressed cakes in it, is suspended by the latch indicated and the sliding base drops away from it enough so that it can be slid over to the ejecting position shown. The press is then pumped up so that the plunger pushes the cakes out of the cage. As the press is backed down again, the cage is held by the latch so that the sliding base may be pulled back; the latch is then released, dropping the cage onto the base which is slid over to filling position again. This leaves the cakes and the filter plates in front of the operator, ready for the cycle to be repeated.

The operating capacity and yield of oil with this press are just as large as a power operated press will give. The press is supplied with either 7-inch or 9-inch diameter cage.

The 9-inch diameter cage gives 1,000 cubic inches of space for each filling and 2,400 pounds per square inch pressure on the material. The 7-inch diameter cage gives 600 cubic inches of space for each filling and 4,000 pounds pressure per square inch on the material.

The 9-inch cage gives a larger working capacity. The 7-inch cage is of smaller capacity but gives a higher pressure on the material and an increased yield of oil. This is best adapted for most oil-bearing seeds, etc., where the highest yield of oil is desired rather than handling the largest volume of material.

Presses arranged for power operation, with hydraulic pump fitted for belt drive, etc., can be also obtained.

Pot Presses.—The pot type oil press is in effect a very high pressure filter press which will handle semi-liquids or heavy materials at high pressures. Aside from pressing of oils this type of machine may be used for various other purposes under pressures as high as 5,000 pounds per square inch, or more if desired.

The presses are generally made with two sets of pots for receiving the material to be pressed or filtered, arranged so that one set is over a hydraulic ram being pressed, while the other set is out from over the ram having the pressed cakes removed from it and being refilled. By alternating in this manner substantially continuous pressing is obtained.

The material to be pressed is confined in a series of cylindrical pot units as shown in line drawing (Figure 126). The pots

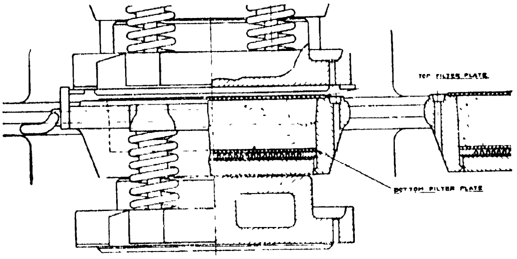


Fig 126—Part 1

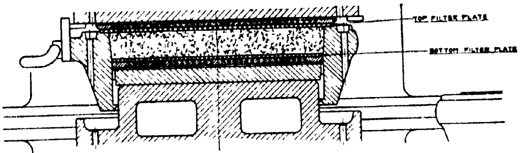


Fig 126 Part 2

have movable bottoms with holes or perforations and outlet channels for the oil or liquid being filtered out. Above the pressing position of each pot is another drilled plate similar to that in bottom of the pot. Material to be pressed is filled into the pots with the filter pads or plates below and above. After the filled pots are brought into place the press, in closing, jams the top filter pads so that only the liquid matter can escape and this must flow out through the filter pads. As the pressure is increased a cake of material forms, and very high pressure can be put upon it to force out the liquid matter.

Higher pressures can be exerted on material than in the oil presses generally used because the cakes are confined at the edges and receive pressure uniformly. This is the only type of press that is designed to handle a semi-liquid or practically a liquid mass in such a manner.

Until within the last few years the pot type of press was made only in Europe, where it was used especially for pressing cocoa

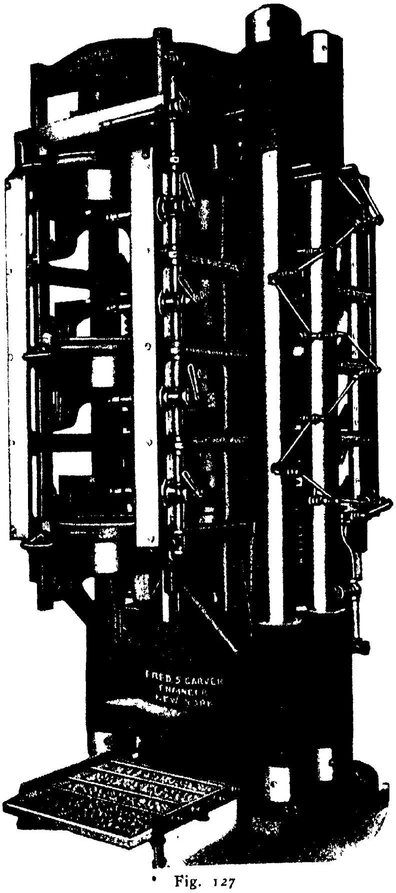


Fig. 127
Pot Press

butter. Within the last few years, however, these presses have been developed in this country by F. S. Carver, who added to them several mechanical and automatic features, such as an automatic filling system, spring pot closing arrangement and mechanical cake ejecting apparatus which eliminate much of the hand labor that is necessary with the European machines.

As this type of press has, until recently, only been known in connection with certain special uses, there will doubtless be found many interesting applications for it other than in the pressing of oils, where separation of the liquids from solid materials under very high pressures is required.

Figure 127 is a side view of a pot press showing five pots filling and five pressing. The heavy construction used to withstand the high pressure is clearly illustrated.

Curb Presses.—Curb presses are used for pressing lard, grease and tallow from scrap and cracklings, oils from fish, tinctures, whitings and such materials. For making wine a wooden curb, made with staves and bands is used in some sections of Europe instead of the more customary method of racks and cloths.

The curb is a round receptacle for holding the material while being pressed. It is made of perforated steel boiler plate or of beveled steel slats encircled with steel bands or of wood staves re-enforced with bands. The fluid extracted by pressing escapes through the perforations in the curb or between the slats and flows to the saucer or the truck with the border, on which the curb rests. The curb is usually made with an opening at one side, which is closed with a cam lock or by a rod locking device which when released allows the curb to spring open thus freeing the pressed cheese.

Figure 128 shows a small curb press with a steel perforated curb. The handles on the side of the curb are used for lifting it off the cheese. In larger presses a geared attachment is used for lifting the curb, the chains forming the attachment, hooking onto the handles.

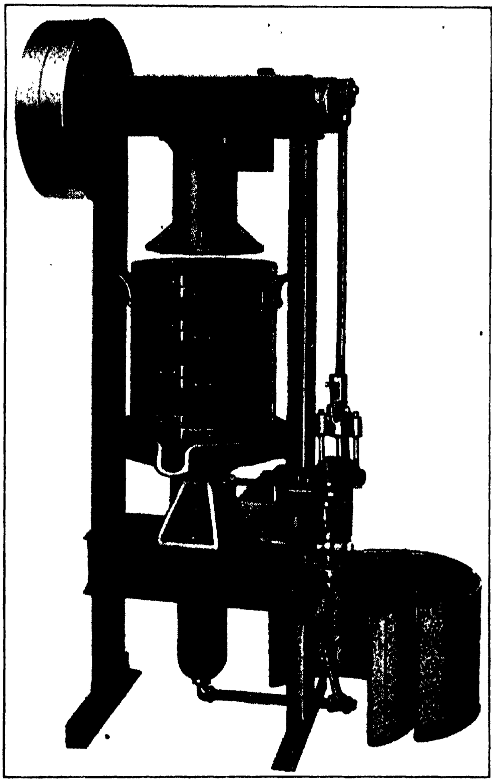


Fig 128
Curb Press

A larger curb press is shown in Figure 129. Here the curb is made of beveled steel slats encircled with steel bands. The lifting device for taking away the curb is also shown.

The operation of a curb press is as follows: When ready to fill the curb, the plunger is swung out of the way. The perforated or bottom plate is dropped into place in the curb and upon this is put a layer of material followed by a division plate, and so on, until the curb is filled. Should there not be enough material to

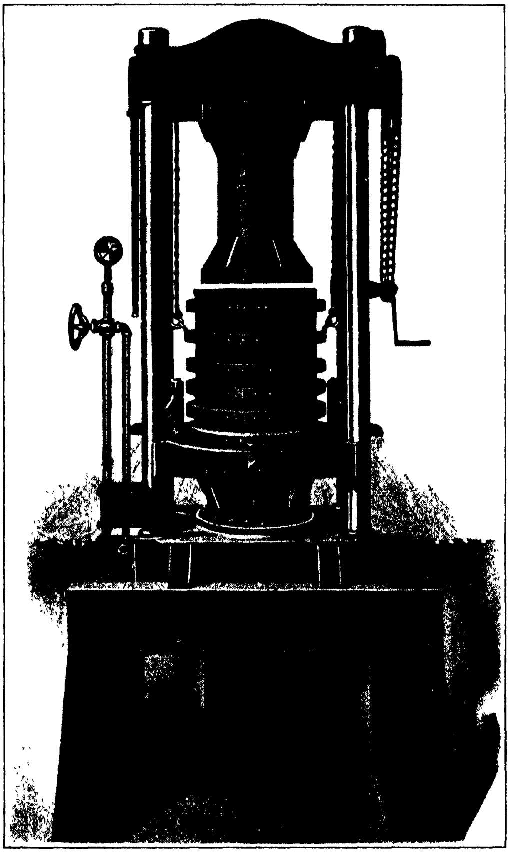


Fig 129
Curb Press

complete the filling, wood blocking can be used which may be fitted into the top of the curb to save time in the rise of the ram. The swinging plunger is now brought into place over the curb. After the pump has been put in motion the ram will be forced to rise by merely closing the operating valve which closes the short circuit escape of the oil or water, used in operating the press, back to the box. The pressure will continue until the maximum has been reached, notice of which will be given by the discharging at the safety valve. The pressure can be continued until the operator desires to release it, which may be accomplished by opening the operating valve, when the press will return to its original position without further attention. The curb is then unlocked, the curb lifting attachment chains attached to the curb handles and the curb lifted from the cheese, which is removed. The curb is then lowered to position, the plunger swung out of the way and the machine is ready for a refilling.

Some of the prominent manufacturers of hydraulic presses are Fred S. Carver, Dunning & Boschert Press Co., Hydraulic Press Mfg. Co., T. Shriver & Co., E. B. Van Atta & Co., Inc., Watson Stillman Co., Worthington Pump & Machinery Corp.

CHAPTER VIII

OIL FILTERS, OIL EXTRACTORS, AND OIL EXPELLERS

It has seemed advisable to divide the subject of oil filtration into three parts, *viz.*; oil filters, oil extractors, and oil expellers.

Oil filters are those machines which are used to clarify the oil itself and they deal principally with waste or used lubricating oils. These oils have not been impaired by their use but have gathered up dirt and impurities which render them unsuitable for further lubrication and it is therefore the purpose of oil filters to remove the foreign material so that the oils may be used over and over again. In order to reduce wear to a minimum there should be a generous use of oil in all kinds of machinery requiring lubricants, as well as oil for cutting and heat-treating purposes. There would be no tendency to use oil sparingly, or false economy in this respect by the manufacturer, if he knew the oil could be reclaimed by filtration, as it can be.

Oil extractors are filters used to remove oil and grease from water, which water as a rule is to be used for boiler purposes. The presence of oil, whether from exhaust steam, or other source, in a boiler causes scale formation which will produce priming and decrease efficiency by retarding the transmission of heat. Such scale is difficult to remove and if allowed to accumulate will cause an overheating of the plates which will weaken them so that they bag and the tubes will become blistered or burned out. A small amount of grease will cause a decided fall in the rate of heat transmission and, therefore, the use of filters or extractors for removing the oil and grease from the feed water is of great importance in connection with boiler feed water. The filtering not only protects the boilers but enables the use of exhaust steam, the heat from which would otherwise be lost.

Oil expellers are machines used to remove the oil from seeds, and perform the same service as hydraulic presses in this respect. It is claimed for them that they yield a superior oil and cake and are more economical to operate than the hydraulic process which has been used for a great number of years.

Anderson Pressure Oil Filters.—The Anderson Pressure Oil Filter is a false-bottomed tank with heavy cloth and filter paper as the filtering medium. The oil is forced through the filter medium from the top downwards, at a pressure of up to 100 pounds per square inch. The filter is used for purifying steam and gas engine lubricating oils, etc., and for drying the moisture from and filtering lubricating oils.

Because of the heavy double filtering medium the oil is readily clarified despite the pressure used, but the process is intermittent and the filter medium must be changed quite frequently if dirty oils are encountered, so that its use has been rather limited

Burt Manufacturing Company.—The American Oil Filter, the Burt Unit Filter, the Cross Oil Filter and the Warden Oil Filter are the four main types of filters made by the Burt Manufacturing Company. The first two are used for the filtering of lard, cylinder, gas engine and heavy oils while the last two are more especially for the cleaning of engine and common machinery oils. All the filters are so constructed that any kind of filtering medium (bone-black, raw wool, common white waste, excelsior, sponges, filtering cloths, etc.,) may be used, as desired. This is of convenience in enabling the use of a particular medium for special work when the occasion may arise.

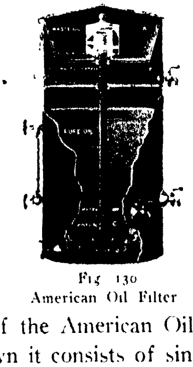


Fig 130
American Oil Filter

The construction of the American Oil Filter is illustrated in Figure 130. As shown it consists of single filtering cylinder in a round chamber, having a hot water compartment at the top which surrounds the unfiltered oil. This hot water chamber makes the oil thin and easy flowing so that filtration is readily accomplished. When operating, warm water is entered at the top until it flows out of faucet (2), then the upper chamber is filled with water and the steam (exhaust) connections made. Hot water from a gas engine may be used instead of steam and continuous flow connections made wherever gas engines are used in place of steam engines. After making the hot water connections, chamber "A" is filled with waste oil. The oil filters horizontally, and the heavy particles of dirt and grit settle in the sedimentation pan. The oil passes from chamber "A" to the filter cylinder and through the filtering material, then down tube "B" to filter plate "D" where the pressure of the oil above overcomes the resistance offered by the weight of the water. The oil here spreads out in a thin film, becoming thinner and thinner as it travels from the center to the outer edge of plate "D." The oil is thus completely exposed to the action of the water. This is repeated as the oil flows against plates D′ and D″. The dirt and grit that is washed out in the water settles by gravity in chamber "E," from where it can be drained to the sewer by opening the valve. The pure oil is drawn off from faucet (1) as needed.

This filter may be used for gasoline and with or without water as desired and therefore is quite flexible in operation. It possesses the great advantage of heat to thin the heavy oils so that they flow readily and in this particular is superior to many other makes of oil filters.

The Burt Unit Filter is of the same general type as the American Oil Filter except that it is square-bodied rather than round and it has two filtering cylinders instead of one. The filter is constructed so that it may be used with or without an oiling system and with or without water. The dirty oil enters the waste oil receptacle, Figure 131, and passes through the small perforations, flowing horizontally to the two filtering cylinders, as in the case of the American, the heavy impurities falling by gravity to the sedimentation pan. Each cylinder is wrapped with a cloth through which the oil must pass before entering the filtering cylinder. After percolating through a quantity of bone black, the oil passes down the two tubes into the bottom of the filter. By means of the plates it is washed as before described and the impurities flushed out when necessary. In cleaning, the filter is opened, the filtering medium replaced, and if the filtering material must also be changed this can be taken out at the same time. As there are two cylinders one can be shut off and cleaned without stopping the operation of the apparatus. This last feature mentioned is an advantage over the American filter and it possesses the same great advantage of heating

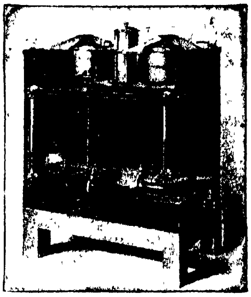


Fig. 131
Burt Unit Filter

The Burt Automatic Water Separator, Figure 132, may be used in connection with any of the oil filters and when used with some of the Burt Unit Filters it is made part of the filter itself and takes the place of the waste oil receptacle. In operation water is poured in at the water and oil inlet until it runs out of the water outlet when it will be ready for continuous operation, the water passing off to the sewer and the oil to the filter.

Although the Burt Unit Filter is intermittent in operation, in that it is not self-cleaning, the apparaus gives very excellent results and the cost of maintenance is low.

The Cross Oil Filter is made in three main styles, the regular style, style "A" and style "B." The differences of styles "A" and "B," from the regular are that in the first case where oils are used in large quantities pipe connections are made by means of gate valves so that the oil may be pumped to any part of the plant, and in the second case (style "B") an attachment is made for the sep-

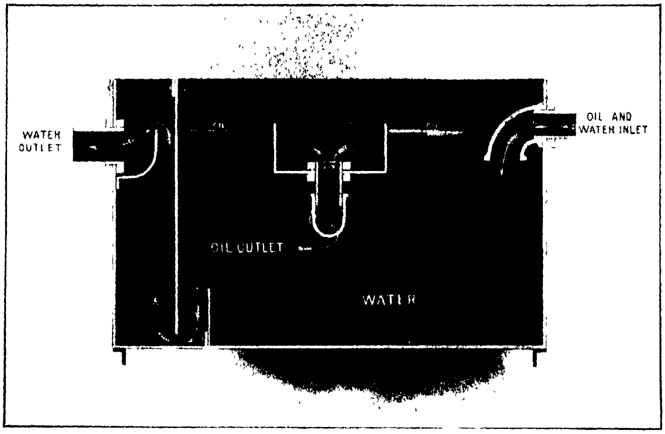


Fig. 132
Burt Automatic Water Separator

aration of water which has become mixed with the waste oil, while in the regular style neither the gate valves nor the water separation attachment is used. Figure 133, illustrates style "B" but will serve for the three, as the method of operation, etc., is the same for all.

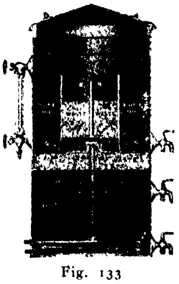


Fig. 133
Cross Oil Filter

When ready to start the filter waste oil is poured into chamber "A." The oil passes to chamber "B," through the layer of waste, which collects all the heavier impurities and from thence it goes through the perforated bottom of the chamber "B" downward in the direction shown by the arrow in the tube "C." From here it passes to filter plate "D" where the increased weight of the water has a tendency to keep the oil back in the tube. As in the other filters the oil is spread out in a thin film and flows over and under plates 1D and 2D. From chamber "E" the oil again filters through a stratum of filtering material "F" and rises to chamber "G" to be drawn off to the pure oil reservoir.

Cross Filters may be used also for cleaning naphtha, gasoline, kerosene, etc. As the filter only has to be cleaned at intervals and as the cost of the filtering material (waste) is very low and yet effective the machine is inexpensive to operate and gives positive results.

The Warden Oil Filter is one of the simplest of oil filters consisting as illustrated in, Figure 134, of a false bottom tank,

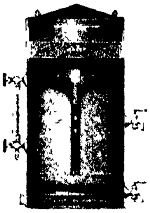


Fig. 134
Warden Oil Filter

a waste oil compartment, a waste compartment, a perforated tube, and a pure oil chamber. In operation the bottom chamber "D" is filled with warm water, heated by means of a steam coil passing through the filter under the false bottom, and the waste oil is poured in at the top of the machine. It passes through the pan of waste which cellects nearly all of the impurities. The oil now passes into chamber "A" and through the perforated tube "B" to perforated filter plate "C" where as in other cases the increased weight of the water has a tendency to keep the oil back in the tube and causes it to spread out in a thin layer. The impurities settle out in chamber "D" to be removed through cock (2). When the oil separates at the water line it is pure and can be drawn off from cock (1).

The filter can be cleaned very quickly without changing any of the connections or interfering with the supply of pure oil. It is constructed to use any filtering medium and to employ heat to aid in filtering and unless the oil is very dirty or heavy it operates efficiently.

Daisy Oil Filter—The Daisy Oil Filter, Figure 135, is a small machine made by the Karl Kiefer Machine Company for handling limited quantities of oil by means of an open gravity filter bed. The idea is that the dirty sediment will be deposited so loosely upon the surface of the filtering sheet that it will offer little obstruction to subsequent filtration.

The filter has an area of eleven square feet and can be used for the filtering of light or heavy oils, the filtering medium to suit the oil being used.

The Daisy Oil Filter is very simple in construction and requires no attention except for replacing the filtering pads. It gives a clear filtrate and is inexpensive to install, but the rate of filtration

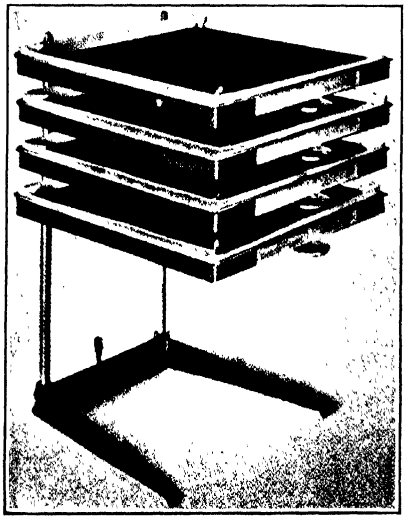


Fig. 135
Daisy Oil Filter

is slow compared with pressure machines and it can not be used for handling large capacities.

Erie Oil Filter.—The Erie Oil Filter, made by the Jarecki Manufacturing Company, is a pressure filter designed to filter waste oil under heavy pressure. It is used to purify waste oil in power, electric light and railway stations, mills, refrigerating plants,

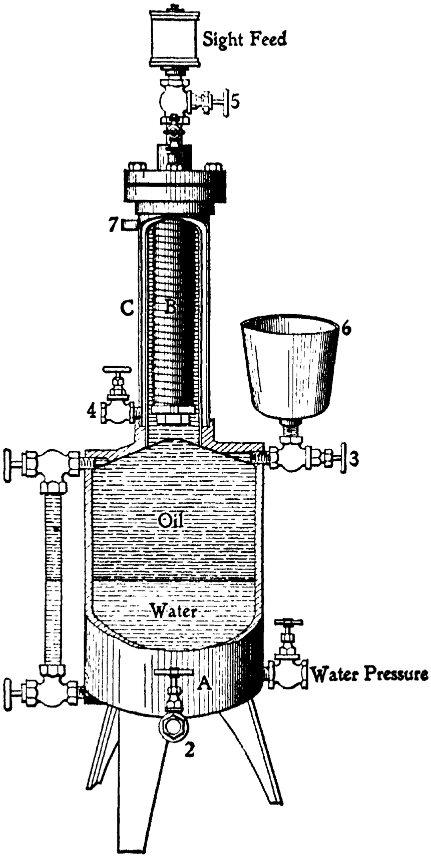


Fig. 136
Erie Oil Filter

steamships, hotels, on screw machines and lubricating oil in general.

In, Figure 136, is shown the general appearance of the machine which is made of cast iron capable of withstanding 200 pounds pressure. The water gauge is the full length of the receiver, showing the height of oil and water therein and at the bottom is an extra heavy hand cock for emptying the water after the oil has been filtered. The small valve at the bottom is for water or steam pressure, the pressure being used to force the oil through the filter in the top chamber. At the top of the receiver is a valve with a large funnel for filling the receiver with oil to be filtered, and also in the top of the receiver there is screwed a steel pipe, around which is a larger pipe fitting into a recess at the bottom and the top flange, forming a heating jacket. At the top and bottom of this jacket are connections for the inlet and the outlet of steam. At the top is a bolted cap screwed on the perforated tube around which is wound the filtering medium. On the top of the cap is a sight feed with a valve and union. The sight feed is filled with water, and the filtered oil can be seen passing through the water showing whether the quantity and quality are what is desired. The quantity can be regulated by the valve and the filtered oil may be piped to any part of the building.

As illustrated in, Figure 137, the perforated tube is first wound with a piece of cloth used only to prevent the filtering material, a silica mixture, from pressing into the holes and the fine fibres of the filtering material from getting into the filtered oil. The filtering material is wound over the cloth layer, lapping each layer and winding to the top of the tube with only enough thread left to start the cap. The screw cap is then screwed on, compressing the filtering material longitudinally.

To operate, the oil to be filtered is poured into the receiver through the funnel (6). The air cock (8) is opened to allow the air to escape, valve (3) is then closed and the pressure is turned on a little through the water pressure valve when the oil appears at the air cock (8) at the top, the cock is closed and the feed is

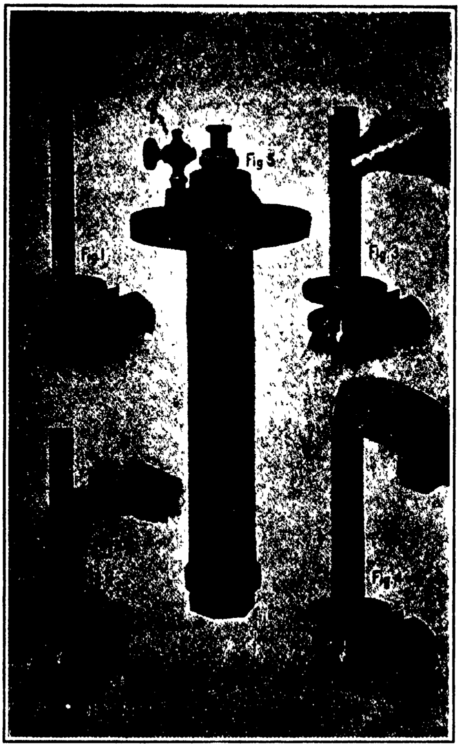


Fig 137
Parts—Erie Oil Filter

regulated by valve (5). The oil being of a lower gravity than the water, the body of water will force it through filter (B). When the oil is filtered out of the receiver, which can be seen by the gauge glass, the pressure is closed off, the air cock and the waste cocks are opened and the filter is ready for refilling.

The filter is made in sizes of from 2-38 gallons per day capacity and although the filtering material may be burned and thus renewed the process is in batch lots so that it is not suitable for large capacities where continuous operation is desired.. One-third of a pound of this material will pack a No. 1 filter tube, and will filter from 60 to 80 gallons of oil in thirty days. The material may be burned off and used three or four times before being destroyed. To burn off filtering material, it is unwound from the tube and laid out so that the strands do not lay over each other; it is lighted and when all the oil is burned off it is dipped into water while hot, and rewound while wet. It should not be put on dry after burning off the oil.

The Blackburn-Smith Grease Extractor.—The Blackburn-Smith Grease Extractor made by James Beggs & Company is practically the same machine as the feed water filter described in Chapter IV. The machine is especially used for exhaust steam from the prime movers of power plants in order that the heat value of the steam may be conserved. The filters take the place of exhaust line separators or skimming and eliminating devices attached to open heaters or tanks. They have the value of positive results as they remove not only the oil in mechanical suspension but also the volatile constituents of the lubricants which go through in the form of gases and condense with the steam.

Ross Water Filters.—The Ross Valve Manufacturing Company make feed water filters for land and marine boilers. Their function is to remove oil from feed-water, wherever a condenser is used in order that the water may be used over again. The filters are connected into and form part of the feed-pipe, being located usually between the feed-pump and the boiler.

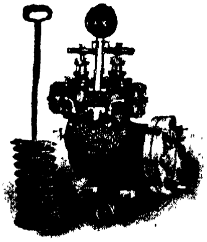


Fig. 138
Ross Oil Filter

As shown, Figure 138, the central portion of the chamber is occupied by the filter, which extends horizontally the whole length of it. The filtering material employed is linen terry (Turkish toweling).

The filter consists of light circular bronze sections of open lattice work, held together by long bolts extending through the whole, Z, Figure 138. The toweling, which is in the shape of a bag and much larger than the skeleton, is drawn over it and drawn down between each of the sections by means of strings wound around it. The filtering surface thus provided is very large, being from 150 to 1,000 times the area of the feed-pipe, according to the service required. The water then passes slowly through the filtering material into the interior of the skeleton and out at the left hand end, and thence to the boiler, as indicated by the arrows. The oil or other matter separated from the water accumulates on the outer side of the filtering material, and in time begins to offer appreciable resistance to the free flow of the water. This resistance will be indicated by the difference in the reading of the pressure gauges shown and when this difference reaches two or three pounds the filter may be cleaned by reverse washing in position or by changing the filter. It will be noticed that valve "A" has a face on both its upper and lower sides, and that it seats upon both the upper and lower bushings. If the valve is screwed down the feed-water passes to the boiler without passing through the filter. If valve "B" is then closed and the drain-cock at the bottom opened, the head "F" may be taken off, the clogged filter removed and the clean filter inserted, the entire operation usually not taking more than five minutes.

For washing the filter without removal, valve "A" is first closed or screwed down, and then "B" is closed and the drain-cock is opened. Valve "A" is then opened a little, and the current thus created around the filter washes the outside of it. By shutting valve "A" and opening "B" the current is made to wash the interior of the filter, or to wash through it from the inside. The long rod attached to the spare filter is merely a handle used to place it in position, and is unscrewed and removed before the cover is put on.

The filter is made strong enough for the high pressures employed in modern practice, being tested at 500 pounds. To start the filter first open the outlet and then the inlet valves but to wash the filter the inlet valve is shut down first and then the outlet valves. The drain cocks are opened for washing, then the inlet valve is opened a little to wash the outer part of the internal chamber. Next the inlet is shut and the outlet is opened a little, this will cleanse the inner part of the chamber.

The gauges show the pressure on the inlet and outlet side of the filter to indicate when the filter should be washed or changed.

The Sims Oil Filter.—The Sims Oil Filter is designed to remove impurities caused by the passage of the oil through bearings. The filters are made in a variety of sizes, the smallest being for small power plants and gas or gasoline engines while the larger sizes serve all kinds of engines and power plants. For large capacity

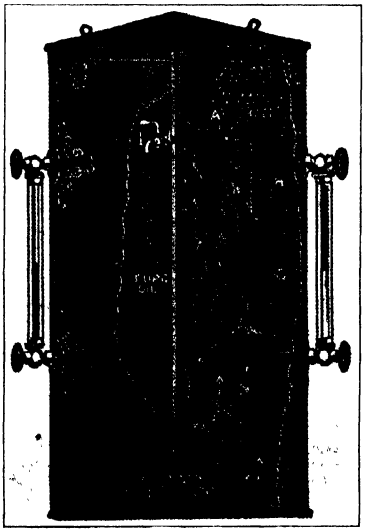


Fig. 139
Sims Oil Filter

a double filter is made enclosed in a single container but otherwise the same as two distinct units.

The interior structure of the filtering section consists of tank "A," Figure 139, to which is connected a tube having attached to it certain cone deflectors; connected to the bottom of tank "A" is a coarse mesh wire screen cylinder "G." This cylinder is covered with suitable filtering material, "H," through which the oil must pass on its way to the clean oil section. Inside of tank "A," in the smaller filters, is placed a perforated bucket into which the dirty oil is poured. The larger sizes have a receiving tank and are provided with automatic overflow when required, for continous oiling system.

In operation the filtering section is filled with water up to the point indicated in the illustration and marked on the filter; the oil to be filtered is poured into the bucket which will remove the coarse impurities, the oil will then descend through the tube as indicated by an arrow. Having reached the cone "C" it will ascend through the perforations and gather on cone "D," leaving this it will gather on the inside of cone "E," the diameter of this being greater than "D;" leaving the same through the perforations, it gathers on cone "F" and ascends into the body of oil floating on the surface of the water. These cones render valuable service by way of distributing the oil in a thin film over a large surface as it passes upward through the water, giving a better opportunity for washing.

Having reached the inner portions of cylinder "G," the oil passes through the filtering cloth "H." The advantage of this upward filtration is that a large area of filtering surface is obtained, which is represented by the entire area of the cloth from the surface of the water to faucet "I." The effect of this large filtering area is the slow movement of the oil being filtered.

When the level of the oil has reached the faucet "I," it begins to pour into the clean oil section. This faucet is designed to regulate the filtration, and it is closed to a point where nearly all of the oil in tank "A" has disappeared before the next quantity is poured in, as the slower the process the more complete the filtration. The supply pipe of the oiling system is connected with the globe valve and a large faucet provides means for filling the oil cans.

In cleaning, the inner structure of the filtering section is removed, the filtering cloth is taken off and washed carefully. The cylinder, cones and pipe are cleaned and the dirty water is drawn off. Clean water is then supplied, the cloth replaced on the cylinder and the process continued as explained above.

American Steam Gauge & Valve Manufacturing Co.—The American Steam Gauge & Valve Manufacturing Company make a filter to remove oil, grease or other suspended matter from boiler feed water, called the American H_2O Grease Extracting Feed Water Filter, Figure 140. In this filter the grease and oil are removed by

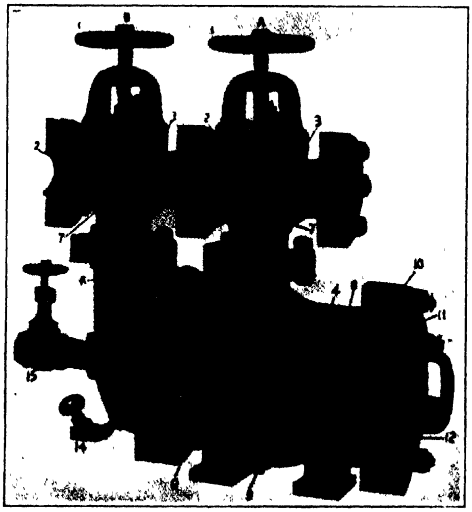


Fig 140
American H_2O Grease Extractor

filtering through linen Terry cloths wrapped around heavy cages, which have an area many times greater than that of the inlet pipe. The filter operates by simply inserting it in the feed water line and leaving it without attention until the cloths become clogged when it is opened and new cloths placed on the filter cages. This change takes about half an hour and the cloths are inexpensive. The filter gives good satisfaction unless the impurities present rapidly clog the filtering medium in which case frequent replacement of cloths is necessary.

Anderson Steam and Oil Separators.—The Anderson steam and oil separators are illustrated in, Figure 141. The cone-shaped

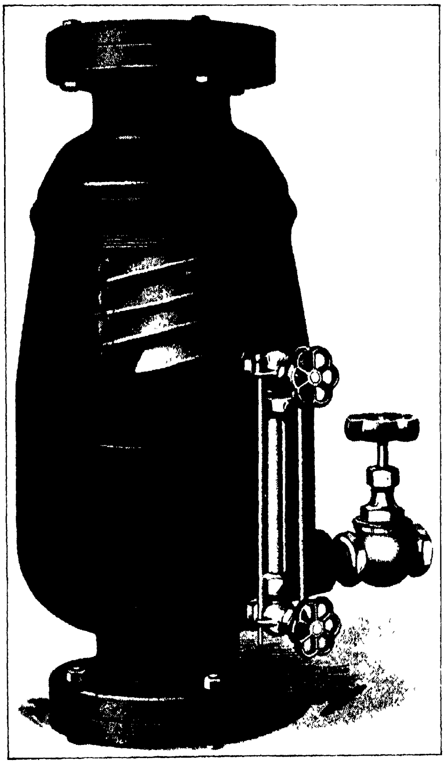


Fig. 141
Anderson Steam and Oil Separator

cap in the head guides the stream through the spiral vanes, imparting a centrifugal motion to the steam, and, without reducing the steam pressure, throws the water to the outside of the case where it passes down the receiving chamber. This receiving chamber is provided with a baffle ring which prevents the moisture from again mingling with the steam.

Where the oil separator is used in the exhaust line it should be placed as near the engine as possible in order to avoid a reduction in velocity of the steam between the engine and the separator. The apparatus is also used for removing oil, water and gasoline from natural gas mains and for removing water and oil from compressed air lines.

Deoleizers.—Oleite is the black granular insoluble mineral substance having a crystalline base which is used by the Oleite Corporation for their oil filters. The emulsified oil from heating systems or the condensates from a surface condenser are absorbed by the oleite which when saturated can be burned and thus rejuvenated. The filter is not for the removal of oil from exhaust steam but for condensed water only and therefore is used in conjunction or in addition to an oil extractor. The filters also are used to remove organic matter, infections and discoloration from ponds, streams, lakes, and well water for domestic and industrial purposes, as mentioned in Chapter III.

The apparatus differs from the ordinary filter in that while the water is cleaned by passage through the machine the cleansing is accomplished by the absorption of the oil by the oleite rather than by mechanical filtration through fine voids. The effectiveness therefore of the process is dependent upon the affinity of the oleite for the oil and when saturation is reached the oil ceases to be removed until the oleite is replaced.

The filter consists essentially of four principle parts, the base, the shell, the head and the cover. Operatively it is divided into four spaces by perforated diaphragms as illustrated, Figure 142. The oil returns or condensates enter near the top through a flanged nozzle and the cleansed water leaves near the bottom through a similar nozzle. Both of these nozzles are furnished with companion flanges and are usually on opposite sides. Entering the head, if the returns contain any free oil it rises and accumulates in the oil space in the concave cover, out of the way of currents. The free oil can be drawn off as required at the oil blow, and if of good quality, can be used a second time.

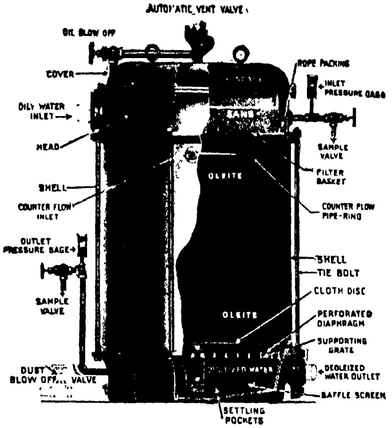


Fig. 142
Oleite Oil Filter

The shell is formed of steel plate, welded or riveted, and packed into the cast iron base and held by asbestos re-enforced packing which is unaffected by temperature.

The oleite with an intermediate cloth screen rests on a diaphragm of non-corrodible metal perforated with fine holes very close together. As this diaphragm would not have sufficient stiffness to support the weight of oleite upon it, it is backed up by a cast iron grating filled with large circular holes to allow a free exit for the purified water. The diaphragm rests on little rounded knobs projecting above the grating, but so small that they do not obstruct any of the perforations. The whole area of the diaphragm is therefore effective.

Any fine particles of oleite that may accidentally pass the perforated diaphragm being much heavier than the water sink through the dead water space in the base and drop through a closely perforated baffle-screen into the settling pocket below, where they are out of the current and can be blown off as desired.

The cover and base are ribbed inside and out, thus giving adequate strength to a light casting. The cover is packed on to the head with a rubber tubular packing and is held down firmly by bolts.

Low pressure gauges and sample valves are tapped into the head and base respectively. The difference in reading on the gauges indicates when the oleite is becoming unduly clogged and samples of the emulsion and deoleized water can be drawn at the respective valves for comparison.

The oleite will become sufficiently clogged at intervals of anywhere from one month upward, depending upon the amount and character of oil.

In order to clean, the cover and spray plate are taken off and the oleite is removed completely down to the cloth screen. Fresh oleite is then filled in up to the top of the shell.

It is important that the filler line in the base be connected with the city pressure or other source of fresh water supply. This enables any fine particles to be washed out of the pockets in the base. It is very necessary before the returns are admitted that the whole deoleizer be filled from the bottom through the filler valve with fresh water until it shows at the air vent in the cover. Otherwise the sudden in-rush of a large volume of returns might wash the oleite out of place.

Anderson Oil Expeller.—The Anderson oil expeller is produced by the V. D. Anderson Company to replace the hydraulic process used to extract oil from seeds. The expeller is also adapted for small factories manufacturing paints and varnishes especially as it will give a full yield of linseed oil without continuous operation. As the oil is practically cold pressed, the meal being warmed to 140° F. in the tempering apparatus, the albumen remains in the cake and the linseed oil will not break but remains clear at a temperature of 800° F. For this same reason it is claimed that cotton seed and other edible oils are sweeter and easier to refine and the cake containing the albumen on the other hand is more digestible. The expeller may be used on almonds, apricot kernels, castor beans, cocoanut skins, copra, corn germs, cotton seed, flax seed, mustard seed, palm kernels, peanuts, poppy seed, rape seed, sesame seed, soya beans, sunflower seed, and tung nuts.

The Anderson oil expeller is continuous in operation, the pressing of the seed being performed in a perforated hardened steel cylinder, in which revolve a series of hardened steel screws mounted on a shaft and so arranged as to produce a gradually increasing pressure. The degree of pressure is regulated by a hardened steel cone. The oil is expelled through the perforations in the cylinder, drops into the oil strainer, and from thence into

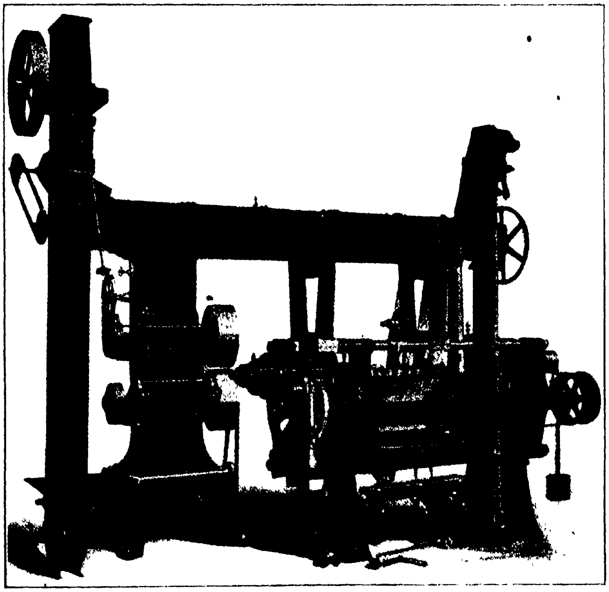


Fig. 143
Anderson Expeller

an oil pan. The foots accumulating in the strainer are fed automatically into the elevator which returns them to the feed hopper. The pressed cake is discharged at the opposite end of the cylinder.

Figure 143, shows the front elevation of a complete one expeller oil plant. The seed is spouted into the roller mill and after being ground is elevated into the tempering apparatus. In passing the entire length of the tempering apparatus it is slightly warmed and then drops into the hopper of the expeller.

All seeds can be pressed cold, and without grinding, but the best results are obtained by flattening and coarse grinding the seeds in a suitable mill (the same type of mill cannot be used for all kinds of material) and then slightly warming the ground stock in a tempering apparatus before introducing it into the expeller. By this method a maximum yield of oil is obtained, without injuring the quality.

The capacity of the expellers range from 450 pounds per hour on peanuts to 800 pounds per hour on copra for the standard size machine. The oil coming from the expeller must of course be filtered and this is usually done by means of a filter press.

It is claimed that the expellers, besides the advantages of cold pressing, cut down the power consumption, labor requirements and cloth replacements.

Centrifugal Machines.—Oils are being purified and reclaimed by centrifugal machines in numerous plants and with very satisfactory results. Inasmuch however, as stated in Chapter V, the construction of the machines, their method of operation, etc., is the same as the De Laval Clarifier, no additional discussion is here needed, except to state that the machines are used for lubricating oils, cutting and heat treating oils and the removal of water from fuel oils.

Vegetable and Mineral Oil Filtration.—There are no special filters made for the filtration of vegetable and mineral oils. Filtration is accomplished by means of standard filter presses, leaf filters or rotary filters with little or no modification.

MAY 1927

INTRODUCTION

Filtration defined in its broadest sense is purification and as such, plays a primary rolé in all the activities of life, from the phenomenon of plant osmosis to the ordinary straining of breakfast coffee. It occurs constantly on every side, although it is seldom noticed or appreciated as such. The seepage of rain water through the ground filters out the silt and humus giving the clear, sparkling water of the spring and brook, mining and manufacturing are accompanied by constant washing and draining, in other words, filtration. In fact the very air we breathe is filtered, by passage through the nostrils, before entering the lungs.

In order to cover in a comprehensive manner this vast range of activities and accurately tabulate all data pertaining thereto an almost inconceivable amount of time and space would be required and such an attempt would not only fall short of its goal but because of its very size and bulk would be practically worthless.

Filtration, therefore, as it is commonly understood has been restricted to mean the removal of suspended solids from gases or liquids by means of a porous medium. Even this classification is often considered too broad and the clarification of gases is omitted, although it properly belongs under this heading.

In this book gases are discussed to some extent, although the greater part of the text is concerned with the removal of suspended solids from liquids. The first part of the book deals with the general laws of filtration, its development up to the present day, and the better known patents and inventions. Because of the limited records available it has been difficult to trace accurately the historical development and place patents and inventions in their proper chronological order.

The second part of the book takes up the various types of filters and gives illustrations and descriptions of the construction, operation, application, and claims made for each.

Part three is given over to a discussion of coagulants, filter mediums, methods of carrying on laboratory tests, interpretation of results, statistics from practical experience, and the care of apparatus to obtain anticipated results. The numerous curves and tabulations of results have been obtained from the practical operation of various types of apparatus. Needless to say the data given are very meager and are picked from widely different industries, but it is neither within the scope of this volume nor is information available to fully cover the field. However the text and the illustrations are sufficiently representative to give the reader a good general working knowledge of filtration.

In the appendix there will be found some useful information in the form of charts and tables.

CHAPTER I

PRINCIPLES OF FILTRATION

Filtration is generally considered to be purification by straining or passage through a porous medium, which medium allows the liquids or gases to pass through but retains the solids, and the power necessary for this action being produced by differences of pressure on the two sides of the filter medium.

According to Hatsch when once a material is ready to be filtered the whole problem becomes a physical one and as the basis of the operation is the passage through a porous medium this feature will be taken up first. The size of the pores in the filter medium has an upper limit, the largest number of pores of such size is of course desirable, but this is a technical matter and simply means a choice among comparatively few materials. As soon as filtration begins the pores in the surface of the filtering medium are throttled, more or less, by the particles which settle on them and as filtration proceeds the liquid has to escape through those throttled orifices and through a layer of particles of increasing thickness. The structure of the layer is fixed by the size and shape of the particles and is for any given material remarkably constant. The resistance offered to the flow of liquid varies greatly from one material to another but in all cases it increases as the thickness of the layer increases until the limit is reached, *i. e*, until with a given pressure the rate of flow becomes so small that it is inadvisable to continue the process. This limit is an economic one but it depends roughly upon the way in which the high pressure increases the cost of operation.

The second point to be considered is that of the structure and shape of the particles, not only the power required to force liquid through a given thickness of filter medium and cake, but also the percentage of mother liquor remaining in the cake at the end of the operation is fixed within surprisingly narrow limits. It is only partially affected by the design of the apparatus and by the pressure and actual experiments alone can, in the case of an unknown material, give information as to the amount of liquid retained by it.

The process of washing the residue to remove valuable mother liquor is similar to filtration with two important differences, the liquid passes through a constant instead of a constantly increasing thickness of residue and the process unlike filtration is not self-regulating. To illustrate this last point; if the porosity varies slightly the flow will be more rapid here until the porosity is uniform, which obviously does not happen in washing.

Figure 1 represents a section of a filter medium, showing two of the openings and the probable stream lines and vortices set up by the liquid in its passage into these orifices. Two spherical particles are suspended in the liquid and will obviously be carried as far as possible into the orifices by its flow. This process occurs all over the surface of the medium and the distribution of successive layers of particles depends entirely on the relation between the sizes and the mutual distances of the orifices on the one hand and the sizes and shapes of the particles on the other. If the mean distances between the orifices is considerably larger than the maximum diameters or dimensions of the particles the first layer of particles deposited will be widely separated and may contain particles deposited secondarily on the solid surface of the medium between other particles which as

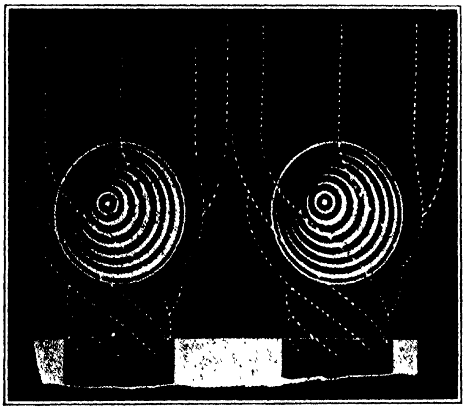


Fig. 1

explained have been carried over orifices. If, on the other hand, the mean diameter of the particles is greater than the mean distance of the orifices, it is obvious that not every orifice can be covered by one particle. The whole problem of the structure of the deposit of solid matter is, therefore, a purely stereometric problem of very great complexity even in the hypothetical case of particles of a definite geometrical shape.

For the purpose of considering a simple case, we choose a medium consisting of agglomerated spherical or cylindrical particles, of which a surface view is shown in Figure 2. The

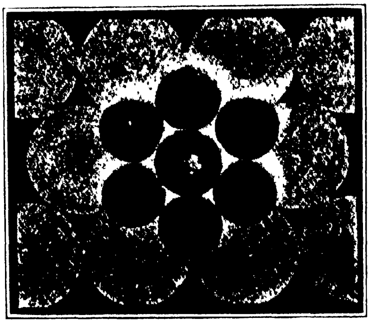


Fig. 2

openings in this filtering surface are, therefore, the spandrils between the circles in contact. If the radius of the circles forming the surface is R, the area of a spandril is 0.162 R^2. In an area, A, of sufficient size and suitably chosen, there are two spandrils for each circle, so that the total area of the orifices is 0.093 A. To cover this surface uniformly, let us assume spherical particles of such a diameter, that they are in mutual contact when placed centrally over the spandrils, which position they would tend to assume under the influence of the flowing liquid. It is at once apparent that six such particles will place themselves over the six spandrils surrounding each circle, and that a seventh particle, marked +, will be deposited secondarily in the centre of the first six. It is now obvious that the area of each spandril is throttled to a considerable extent. If we make the assumption, which is not strictly correct, that the area obstructed by the particle is the circle cut off on it by the surface of the medium, the amount of throttling is easily calculated. The area of such a circle is 0.0744 R^2, and the area of one spandril, which remains clear, is 0.0876 R^2. The total free area, instead of the expression given above, *viz.*, 0.093 A, is now 0.0502 A, or less than 54 per cent of the original cross-section. The structure of the further layers of the deposit is that of the first layer, *i e.*, they also consist of spherical particles in mutual contact. The arrangement of the passages is however, quite different in the second and further layers as shown in Figure 3. In this figure, the first layer, *i e.*, the layer resting immediately on the medium, is shown in white, and the second layer dark. It will be seen at once that the particles cannot arrange themselves, as in the first layer, centrally over every passage, but only over alternate ones. Half the passages between the spheres of the first layer are therefore uncovered and half of them covered by the particles of the second layer. The latter passages will be considerably obstructed, but the total free passage area is about 30 per cent greater than that of the throttled medium. This structure, as already mentioned, is the same throughout the further layers.

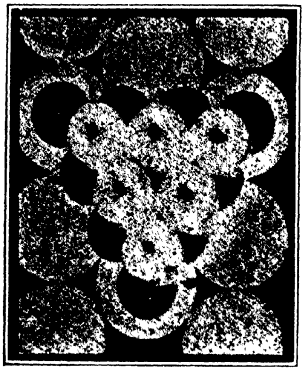


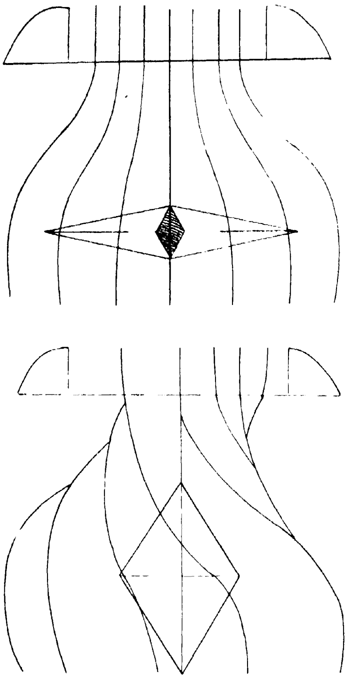
Fig. 3

From this extremely special and simple case, a number of important conclusions may be drawn. The first point illustrated is that a considerable throttling of the free passage area of the medium is caused by the very first layer of particles deposited on the same. This amount of throttling is specific for any given medium and any given size of particles; with a medium having openings of suitable shape and with particles of suitable shape and size, it is possible to stop the flow of liquid almost immediately, and although this case naturally hardly ever occurs in practice, yet the considerable pressure necessary for filtering various precipitates is caused to a preponderating extent by this throttling effect of the initial layer of deposit. In most cases, in fact, the free passage way in every succeeding layer is probably greater than the free passage way left in the throttled orifices of the medium, just as in the special instance selected for illustration. The second point, which is clearly shown by the preceding discussion, is, that the whole structure of the deposit is very largely determined by the size and distribution of the orifices in the medium, and their relation to the diameter of the particles. The particles shown in Figure 2 were chosen of such a diameter as to be in mutual contact when placed over the openings in the medium. If we now assume that the same medium is used for filtering particles of somewhat smaller diameter, say three-quarters of that first shown, the following conditions will prevail:—Six particles will still, by the flow of the liquid, be carried over the six spandrils; they will, however, no longer be in mutual contact, nor with the seventh particle deposited somewhere between them, or, in other words, the percentage of voids in the deposit will be considerably larger than in the case shown in Figure 2. In practice the irregularity of the particles, and the equalizing effect which this irregularity produces in a cake of some thousand layers—a cake of barium sulphate one inch thick contains from five thousand to seven thousand layers—masks this condition, but it can generally be noticed that the surface in contact with the medium is wetter, *i. e.*, has a larger percentage of voids, when the medium is more porous.

A further question of considerable importance is not illustrated in the case of spherical particles, or of regular polyhedra, *viz*, the tendency of particles to align themselves with the stream lines. This depends on the velocity of the flow and on the shape of the particles, which naturally tend to arrange themselves so as to offer the minimum resistance to the flow of the liquid. The ultimate structure of a deposit consisting of asymmetric particles will therefore be settled chiefly by their behavior in the stream lines and modified by such other factors as their relative sizes and the distribution of the pores in the medium. In most cases, however, the arrangement will not be one in which the maximum number of given particles is contained in a given space. In deposits or cakes as generally obtained by filtration, the voids are filled with mother liquor and any treatment which will reduce the percentage of voids will cause liquor to appear, in other words the cake becomes wet. It is a perfectly familiar fact that apparently dry cakes of calcium sulphate and calcium carbonate which break with a clean fracture will be reduced to almost a liquid by shaking.

Particles tend to place themselves so as to offer the minimum resistance to the flow of liquid as the resistance increases rapidly with the increase in velocity. Limit values therefore are possible with particles of a certain shape. If particles have a rhombic pyramid as shown in Figure 4 it may keep the position shown with respect to stream lines if the velocity is small, as even the section at right angles to the latter is such as to offer very little resistance.

With increasing velocities of flow which will have the further effect of producing vortices, the particles will ultimately assume the position shown in Figure 5. In this case it might pass right through the orifices if the cross section is sufficiently small. This explains why certain substances pass through a filter at high pressures when they will not do so at low pressures or when the pressure is gradually built up, but of course applies only to precipitates which consist of rigid particles, whether crystalline or amorphous. Apparently rigid particles are met with even in



Figs 4 and 5

the latter case, for instance, calcium carbonate which from cold solutions precipitates in the form of globules, (Figures 8 and 9, page 14). A vast number of amorphous precipitates, however, cannot be described as consisting of rigid particles, and their behavior when arriving on the medium or forming successive layers must be considerd separately. Figures 10 and 11 page 14, show copper ferro-cyanide precipitated on a slide. These precipitates form skins or membranes apparently possessing a further structure which is not quite clear in spite of the magnifications of the three hundred and fifty diameters employed. Another precipitate of similar character is that of alumina shown in Figure 12, page 14, enlarged about one hundred and fifty diameters.

If a liquid containing particles of such membranes is filtered various conditions may arise according to the velocity of flow. If the latter is great the membrane may be destroyed by the currents and vortices in the liquids, even before they touch the medium and as their ultimate structure is extremely fine they will pass directly through it. In prussian blue, for example, if the pressure at the beginning of filtration is high, this will happen. On the other hand, if the velocities are low the membrane may settle down on the medium and then be torn through where it covers the orifices of the latter. The same thing would happen in successive layers, but with a speed sufficiently low after starting, the filtration would proceed without any noticeable amount of precipitate passing through.

If the membrane is somewhat tough the tearing may cease after a certain thickness has been reached and then filtration will be stopped.

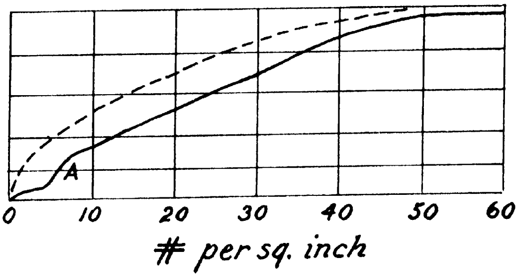
The foregoing relation between velocity of flow and pressure of a given precipitate does not of course apply to different substances.

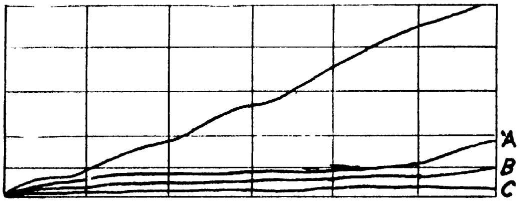
Assuming that two different substances have the same shape but one is larger than the other it is probable that the first will have a small number of large openings and the second will have a large number of small openings between the particles in the same space. If the aggregate area is the same it is obvious that the few large openings offer less resistance to the flow of liquid than the smaller ones.

Figures 13 and 14, page 14, in photo-micrography show respectively calcium sulphate and an organic salt, the crystals of the organic salt bearing a close resemblance to the needles of the sulphate. Both photographs are on the same scale and show the calcium sulphate crystals to be two to three times the size of those of the salt. The behavior of the two precipitates on the filter is very similar, both forming good, apparently dry cakes, of fair cohesion which break with a clean fracture, but while in the case of the calcium sulphate a cake of two to three inches in thickness was easily obtained with a vacuum filter (Pressure about 14 pounds per square inch) the organic salt practically stopped filtering when the pressure had increased to 20 pounds and only one-half an inch cake had been built up. In order to keep the flow equal to that of the calcium sulphate a pressure of 60-80 pounds was necessary.

In close connection with the foregoing is the behavior of precipitates consisting of particles of different sizes and composed of two or more substances. The smaller particles will set in motion more quickly than the larger ones and will reach the filtering surface first. When a precipitate contains some particles notably smaller than the bulk they will either pass through the filter or practically stop it. As even precipitates of uniform composition contain a small percentage of undersized particles it is quite general to see these pass through the filter at the commencement of filtration, after which the filtrate is clear. There is a throttling of the orifices of the medium by the larger particles which succeed the first flow of small ones. The throttled area of each orifice may be so small that it stops even the smallest particles and this is the explanation in somewhat more scientific language of the statement generally made to account for this phenomenon, *viz*, that it is not the filtering medium itself but the layer of precipitate which acts as a filter.

To produce the flow of liquid, which is of course the essence of the process of filtration, it is necessary that a difference of pressure should prevail between the two sides of the filtering medium apart from the capillarity of the latter, which is of no great practical importance. The excess pressure on the filtering side of the medium is hydrostatic, due either to the column of liquid itself or to an artificial column produced by compressed air or a pump. As there are a great many misconceptions concerning the object and the effect of pressure the subject deserves extended consideration. The first object and as shall be seen the only effect of pressure is to produce the flow of the liquid through the medium and through the gradually increasing layer of solid matter on it. Increased pressure produces an increased flow and theoretically the latter is only increased as the square root of the power, if friction is left out of consideration. Friction is present however and pressure is absorbed in three ways, (1) in forcing the liquid through the filter medium, (2) in forcing the liquid through the reduced orifices in the medium and (3) in forcing the liquid through the increasing layer of particles. The resistance specified under 1 and 2 is constant for given particles but for 3 it increases as the layer increases in thickness. Obviously a thickness of layer can be reached which does not permit any more liquid to pass with a given pressure. If the pressure under which a liquid escapes through an orifice is without friction and be plotted as the abscissae and the velocities as ordinates, the curve produced is of course a parabola. Figure 6 shows this parabola, for a certain filter medium, in the dotted line. The velocities of flow at various pressures with water and with the same medium were then determined experimentally and are plotted in full line. It will be noted that the curve has an inflexion at "A" which indicates that at





Figs. 6 and 7

that point the loss of head is at a maximum for the medium under consideration.

Experiments with a number of different filter media and with different liquids all show the above mentioned inflexion.

Figure 7 illustrates in a very striking manner the effect of extremely thin layers of deposit upon the surface of the medium. The top curve shows velocities of flow through clean medium with water. A layer of deposit was then formed by filtering water in which had been suspended a quantity of barium sulphate sufficient to produce on the medium a layer of 0.3 mm, in thickness. The velocity of flow as shown by the curve "a" is reduced to less than one fifth by this minute layer and it will be still further noticed that inflexion is shifted to the right-hand side of the diagram and that the maximum rising occurs at the highest pressure. The two further curves "b" and "c" show the velocity after addition of more barium sulphate up to double and triple, respectively, the thickness of the original layer. Consideration of these two diagrams shows that for any given filter medium the velocity at first increases approximately in proportion to the pressure, with the maximum reached at the point the maximum resistance is reached. After this point as the ordinates of the curve show the velocities become more and more nearly proportionate to the square root of the pressure. Until this point is reached, therefore, the increase in pressure may be justified as producing a saving of time or filter area. Whether it is economical depends upon other considerations.

If a certain quantity of liquid has to be filtered and air at, say, from 15-30 pounds pressure is used alternately the liquid will have to be replaced by the same volume of air at 15-30 pounds. In the first case double the volume of free air must be compressed to form 15-30 pounds pressure and in the second place about 2.4 times that required in the first. It is therefore impossible that the increase in velocity should be proportionate to the increased expenditure of power. These considerations are quite clear but the effect of the pressure on the structure of the solid layer is much less so. The opinion used to be that increased pressure gave a harder and dryer cake especially where filtering was taking place in a closed space as in the chamber of a filter press. In other words increased pressure was supposed to reduce the percentage of voids and bring the solid particles in closer contact. The short analysis of the formation of the deposit previously given shows this view to be wrong. While the particles are suspended in the liquid they are not subjected to unbalanced pressure so that an increase in the latter can not effect them.

As previously stated, if in a mixture of solids and liquids all the solid particles to be filtered off were of uniform size and shape, the construction of the filtering medium would be such that the pores or meshes would be slightly smaller than the particles, unfortunately, however, in practically every case met with in the arts and industries the particles are not uniform in size nor shape. The structure of the filtering medium consequently must be such as to either retard the particles completely or the meshes must be partially throttled by the particles of the deposit.

Often, as in sugar filtration, the cloth becomes covered with a slimy impenetrable layer which retards further filtration. If a filter-aid is used the result obtained by depositing a substance of granular, crystalline or fibrous nature on the surface of the cloth which forms a network, prevents the pores from clogging up. Each successive layer will be a network so that the whole thickness of the layer will be permeable. To assist this it is advisable to work at first with low pressures as the first layer will then be spongy and increased pressure will serve to dry the cake. High pressures do not effect drying of the cake as any non-rigid particles present are forced into the pores of the medium by the increased pressure

All filtering mediums and all cakes must be porous bodies to insure good filtration. Crystalline, fibrous, or granular substances occupy definite spaces which do not completely cover the surface of the filter but pack adjacent to each other's edges and surfaces and thus leave large or small channels, according to the size and shape, which are not affected by pressure and which offer free passage to the filtrate. This causes the filtrate to pass through without retardation, but with gelatinous substance the particles will spread over the whole surface and will block the pores of the filter and stop filtration. Even when needle-shaped kieselguhr, well disintegrated paper pulp or long crystals of sulphate of lime are used with gelatinous materials as filter-aids, the pressure at first must be low to get a clear filtrate.

It is usually desirable when forming crystals to obtain them as large as possible so only a low pressure is necessary. Needle-like crystals form excellent filter-aids as they produce a felt-like mat which gives a clear filtrate with a low pressure. Sulphate of lime if formed under certain conditions is a good aid to filtration but if formed under adverse conditions it is a hindrance.

The need for uniform pressure upon a filter cake is due to the fact that an uneven pressure causes a re-arrangement of the particles so that they lose their free filtering nature. This can be illustrated as mentioned before by taking a cake of sulphate of lime and shaking or patting it and noting how the cake becomes wet and compact.

Chemical text-books give, as a rule, information about the character of precipitates, whether they are amorphous or crystalline and to what system of crystals they belong, but no information as to the size of the particles, which is of great importance from a filtration point of view. To forecast or to understand the behavior of precipitates, microscopic examination is indispensable and very nearly sufficient. Among the most important precipitates are insoluble calcium salts particularly carbonates and sulphates. As regards the formation at the moment of precipitation the carbonate appears gelatinous but the stage does not persist long enough to photograph. Figures 8 and 9, page 14, are taken from two complete precipitations at ordinary temperature (15° C.) both in the form of globules with a very small amount of crystalline particles present. Figure 15 shows an organic carbonate from a manufacturer's sample and Figure 16 a similar sample from precipation in a test tube. Calcite crystals are present in both cases in small quantities. Figure 17 shows a precipitate produced by adding a boiling solution of ammonium carbonate to a boiling solution of calcium chloride. The crystals are large and extremely well formed rhombohedra. Figures 13

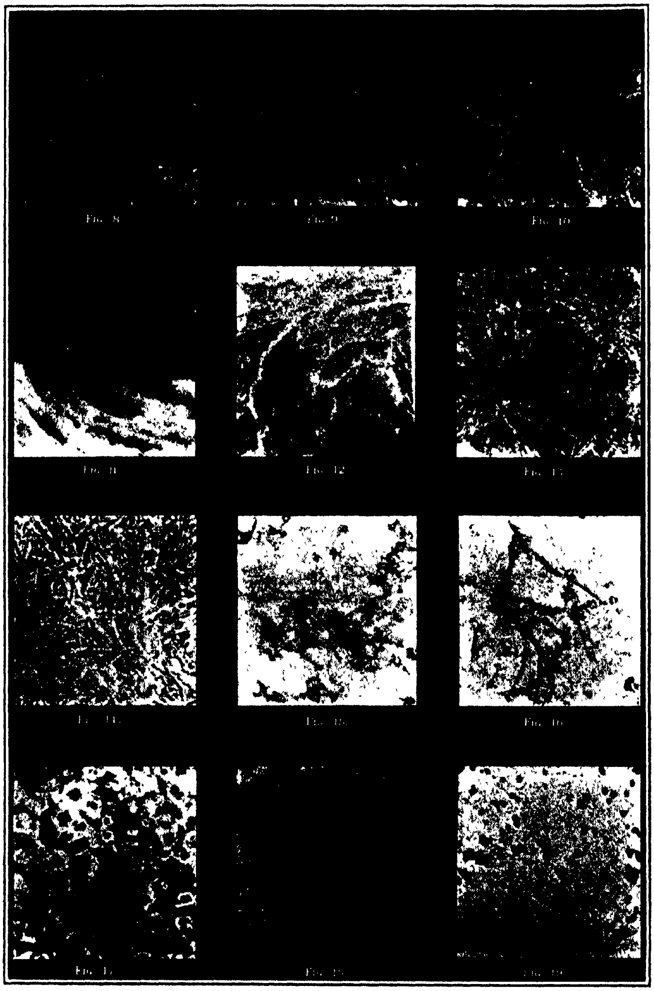


Fig. 8 Fig. 9 Fig. 10

Fig. 11 Fig. 12 Fig. 13

Fig. 14 Fig. 15 Fig. 16

Fig. 17 Fig. 18 Fig. 19

Figs. 8-19
Photomicrographs of Precipitates

and 18 show crystals of calcium sulphate produced by precipitating calcium chloride solution with ammonium sulphate and magnesium sulphate. Sometimes the sulphate forms in the shape of small nodules, Figure 19 shows calcium sulphate, formed from decomposition of calcium chloride with concentrated sulphuric acid. Figure 20 was obtained from a saturated solution of barium chloride by precipitation with dilute ammonium sulphate, both being cold. Figure 21 shows barium chromate in well defined crystals, also of a very small size. Various lead compounds are shown in Figures 23-26.

Figure 22 shows carbonates enlarged seven hundred diameters and sulphates are shown somewhat larger in Figure 23 where they are enlarged three hundred and thirty diameters. A very striking example as regards size and even more striking illustration of the wide lines within which the size of particles may vary according to the different methods of precipitation is presented by lead chloride, Figure 24. Here is shown the salt precipitated from dilute lead acetate by dilute calcium chloride in which case it forms very large and well developed crystals. Figure 25 is a dark ground photograph of another part of the same preparation. If however the acetate is decomposed by hydrochloric acid the crystals are very minute as shown in Figure 26, all being of the same scale of three hundred and twenty diameters.

Magnesium carbonate has a large percentage of water retained by the residue, about 72 per cent, and no probable shape of the particles could account for this large percentage of voids between them, sufficient to retain the above mentioned amount of water and reason therefore has to be sought in the internal structure of the particles themselves. This is confirmed by Figure 27 which shows dry carbonate enlarged five hundred times. It will be seen that the precipitate consists of particles agglomerated in the shape of tubes some of which recall the structure of kieselguhr. Figure 28 was taken to show that the tubes illustrated do not represent the ultimate structure of the material but actually consist of agglomerated particles. The photograph at

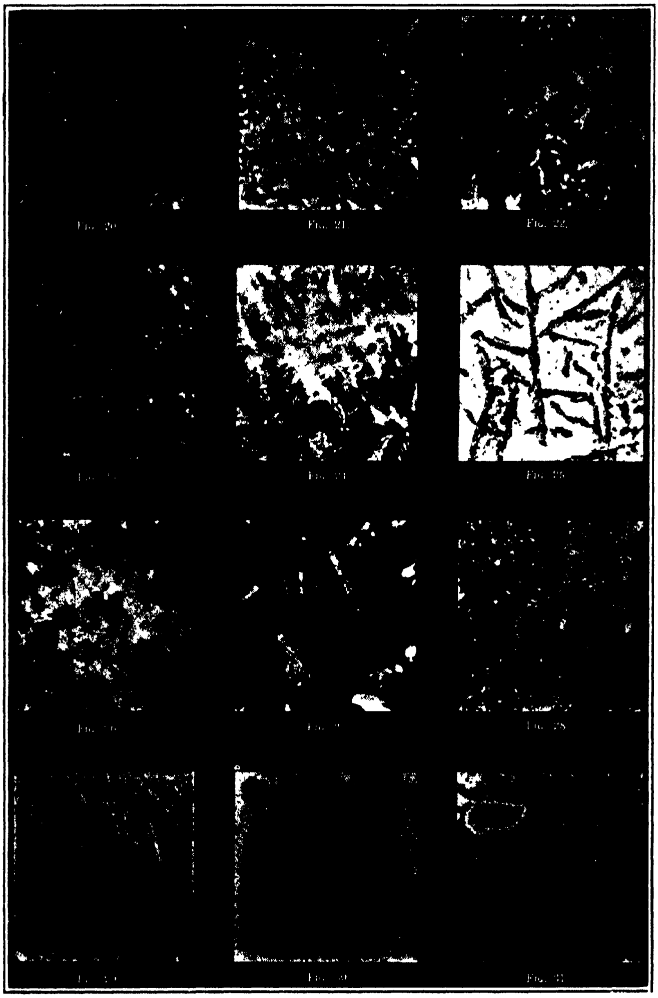


Fig. 20 Fig. 21 Fig. 22

Fig. 23 Fig. 24 Fig. 25

Fig. 26 Fig. 27 Fig. 28

Fig. 29 Fig. 30 Fig. 31

Figs. 20-31
Photomicrographs of Precipitates

five hundred diameters was produced by grinding up a small quantity of dry precipitate and putting it on the slide with the finger tips.

The foregoing illustrates precipitates either crystalline or at least having particles of a definite size. A large number of precipitates, however, come down as membranes, flakes or other aggregation. Copper ferro-cyanide is shown in Figures 10 and 11 and ferrous ferro-cyanide is precipitated in similar masses. Aluminum hydroxide is also similarly formed (Figures 12 and 29). Arsenic sulphide, obtained by de-arsenating sulphuric acid with hydrogen sulphide, is illustrated in a dark ground photograph in Figure 30, the flakes formed being shown. Figure 31 shows crystals of sodium silico-fluoride which are interesting as illustrating the limit at which a product becomes fairly palpable.

The greatest value of microscopic examination for filtration is that it acts as a guide for precipitation. A great number of precipitates can be obtained in different forms with particles of different sizes. The variations are due to—often slight—changes in concentration and temperature of the reacting solutions and are even influenced by the amount of agglomeration. It, therefore, would be easy to make a few comparative tests and settle the method of precipitation, assuming of course that it fulfills other requirements of the case, which gives particles best qualified to behave satisfactorily in subsequent filtration. Even here requirements may differ, as in one case rapid filtration is aimed at and large particles are desired, while in another case a compact cake is the desideratum, etc. The question then of the best precipitation can be solved quickly and easily by comparative trials and microscopic examination of the product

A great deal of investigation work has been carried on by Almy and Lewis to determine the relation between the rate of flow, the pressure, and the thickness or cake. It was found that the rate of flow was the same function of both volume of filtrate and pressure. It was next determined that the rate of flow was a power function of pressure as well as volume of filtrate, as expressed by the formula $R = \frac{P}{KVm}$ where R is the rate of flow in cubic centimeters per minute, V is the volume of filtrate in cubic centimeters and K is the constant varying with the nature of the liquid and its viscosity. The rate of flow in some cases instead of being constant is proportionate to the one-fourth root of the pressure. Assuming that the rate of flow is analogous to that through fine capillary tubes where the rate is directly proportionate to the pressure and to the square of the radius of the openings this low coefficient is readily explained by nature of the sludge used, in the experiments. Owing to its non-crystalline character the residue was easily compressed and consequently with a small amount of precipitate in the press at higher pressures the passage through the cake would be expected to be smaller than at low pressure. A more granular precipitate would more nearly approach unity. If $R = \frac{Pm}{KVn}$ it is only necessary to determine experimentally the values of K, m, and n to calculate the rate of flow at any pressure or thickness of cake desired. The rate is inversely proportional to the viscosity and as far as known depends on various factors, as the degree of dilution, temperature, etc.

As analogous to the flow through capillary tubes the rate of flow is influenced by the area of openings between the particles of the filter medium and the cake and consequently for crystalline particles will have many more larger passages for liquor than less rigid precipitates. Therefore, non-crystalline particles are compressed and any increased pressure will only tend to increase the impermeability of the cake and force the particles into the filtering medium. It must be remembered that one of the most important points to be borne in mind is the arrangement of the particles. If the spheres are so arranged that their centers lie at the corners of a cube the pore space will be 47.64 per cent, while if the center of the spheres lie at the corners of a rhombohedron which permits the closest possible packing, the pore space is 25.95 per cent. Between these limits we may expect to find the porosities of all ordinary materials. With actual material in the case where the grains are of approximately equal size, the pore space and also the diameter of the particles may be readily determined by counting a number of grains and determining their weight and specific gravity.

TABLE I.

Mesh screen	No of grains	Wt in grams	One gram grain 10^{5}	Sp Gr	Pore space Percentage	Diameter Mm
30	300	0.0307	10.23	2.74	35.4	.420
	300	0.0316	10.36			
40	400	0.0251	6.3	2.68	34.1	.354
	400	0.0253	6.3			
50	400	0.0182	4.55	2.73	36.4	.318
	500	0.0246	4.92			
60	800	0.0238	2.97	2.82	36.8	.269
	600	0.0172	2.87			
80	800	0.0202	2.52	2.85	37.7	.257
	600	0.0156	2.60			

Mixtures of small and large grains show surprising similarity in porosity to that of either of them alone. For all practical purposes the pore space for masses of crystals, such as are commonly produced by rapid cooling of crystals, may be placed at thirty per cent of the total volume occupied.

Further experiments with vacuum filtration show that the moisture content increases inversely as the diameter of the grains, as shown in the table below.

TABLE II.

Mesh screen	Moisture content at end of			Vacuum In mercury
	5 min	15 min	30 min	
30	7.2	5.69	4.75	1.5
40	8.2	6.84	5.19	1.75
50	8.65	7.5	6.41	.75
60	8.42	7.38	6.9	2.0
80	9.15	7.52	7.37	2.25

Tests were next run with a centrifuge operating at two hundred revolutions per minute. The sand was transferred to the centrifuge after a 2 minutes dewatering in a Buchner funnel and while still moist, the centrifuge being revolved for 2 minutes.

TABLE III.

Mesh	Vacuum 5 inches	Centifuging 2 inches
30	7.25 7.12	2.26—2.2
40	7.5 7.6	1.93 2.3
50	8.7 8.6	2.56 2.8
60	9.35 8.4	2.36—2.65
80	9.7—9.56	2.49—2.16

According to Griscom the pressure at the periphery of a 4¼ inch centrifuge at two hundred revolutions per minute is 7.6 pounds per square inch.

The retention of small quantities of liquid in the mass is due undoubtedly to a capillarity and the removal of these last few per cent is extraordinarily difficult. If all the residual water were distributed uniformly over the surface of the grains the thickness of the film in sand of thirty-mesh would be 0.0116 mm., when the sand has 6 per cent moisture. As the pore space is 35.4 per cent, the moisture would only fill 30 per cent of this and the remaining 70 per cent would be filled with air, which gives an idea of the comparative inefficiency of the ordinary filter. In the case just mentioned the capillary action of the small spaces between the grains is also of great importance.

When an air chamber is formed in a layer of solids the downward pressure on the water-filled pores is relieved, which is contrary to the centrifuge where the particles of water experience practically the same stress and only the capillarity of the finest pores and surface tension of the films are sufficient to resist its action. The stress, which must be applied to each grain to relieve at least a part of the film of water and to overcome surface tension, if worked out might furnish a scientific basis for the prediction of the behavior of finely divided solids on centrifuging.

The amount of water retained when an ordinary filter is used varies from 11 per cent, with a twenty-mesh material, to 20 per cent, with a one hundred-mesh material, one hour being allowed for drainage.

The two processes of flow of liquid and the building up of the cake are constantly changing as the liquid in filtering leaves solids behind, thus constantly increasing the thickness of the porous mass and at the same time decreasing its own rate of flow, due to the increasing thickness of solids through which the liquid must pass. To get the relation between these two and the laws of each determines some of the fundamental principles of filtration. Sperry has worked out the relation between the two processes—flow through the cake and thickness of the porous mass equal the rate of flow at any instance. The rate of flow varies as the first power of the pressure and not as the square root of the pressure according to the law of falling bodies and flow formulas in hydraulics.

It has long been known that there are two distinct kinds of flow of liquids through tubes, namely sinuous and non-sinuous. If water under very calm conditions is caused to flow through a smooth tube, with a flared inlet, at low pressure and then the pressure is increased gradually the flow for a time through the tube is smooth and even, the rate of flow varying with the pressure. As the pressure increases a period is finally reached in which the rate of flow changes quite suddenly and commences to vary as the square root of the pressure and simultaneously with this event the flow of liquid breaks up into eddies and sinuosities. This particular point is called the critical point and marks the moment of change from one type of flow to the other. The cause of this difference in the behavior of the flow in respect to pressure is due to the fact that in the non-sinuous flow the chief resistance is caused by the viscosity of the liquid, while in the sinuous flow the resistance is caused by friction between the liquid and the walls of the tube.

The temperature has a marked effect on the flow through a porous medium, by affecting the viscosity. Poiseule's formula for eddyless flow is $V = \frac{\pi P R^4}{8LU}$ Where P = pressure, R = inside radius of the tube, L = length of the tube, V = velocity of flow, U = coefficient of viscosity. The effect of temperature

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is shown by the formula $N_t = \frac{N_0}{1+\alpha T+\beta T^2}$ Where N_0 α, and β, are constant for each liquid. T = temperature, N_t = coefficient of viscosity at temperature T. For water N_0 = 0.017793, α = 0.03580, and β = 0.0002253. For acetic acid N_0 = 0.016867, α = 0.01826, and β = 0.00008537. The flow through a filter cake is non-sinuous and the flow varies according to the material. A porous mass is said to have a permeability of one when a unit pressure produces a unit flow through a unit thickness over a unit area under standard conditions of temperature, or in pressure of 1 pound per square inch there is produced 1 gallon per hour through a cake of 1 inch in thickness in a period of 1 hour. Resistance of flow varies therefore inversely as its permeability and unit resistance is resistance which is possessed by a porous medium of unit permeability. The law governing the flow of liquid through a porous mass is taken to be $\frac{dq}{dT} = \frac{P}{RT}$ . . . . "A" Where $\frac{dq}{dT}$ = rate of flow with respect to time, P = pressure of mixture, R = resistance of material, and T = thickness of material. The two things determining the thickness of the cake are the cake-forming ability of the solids (microscopically and experimentally determined) and the per cent of such solids present, other factors being constant. The law governing the thickness of cake, therefore, may be taken to be, $T = \frac{\%q}{K}$ . . . . "B." Where T = thickness of cake, % = per cent of solids present, K = rate of deposition, Q = quantity of discharge. The law of flow through a porous mass is given in equation "A" as $\frac{dq}{dT} = \frac{P}{RT}$. In filtration the porous mass is composed of the deposited solids plus the filter medium. If the resistance to flow by the filter medium be designated by R_m the rate of flow through the filtering medium would be

$\frac{dq}{dT} = \frac{P}{RT + R_m}$ .... "C." $T = \frac{\% q}{K}$, substituting this value of T in formula "C"

$$\frac{dq}{dT} = \frac{P}{\frac{R \% q}{K} + R_m} \text{ or } dT = \frac{R \%}{PK} q dq + \frac{R_m}{P} dq$$

..."D." In this $\frac{dq}{dT}$ is the rate of flow of filtrate If the expression is integrated there results the expression of which $\frac{dq}{dT}$ is the rate of change of discharge Q with respect to the time T. Such an expression is nothing more than the equation of the curve showing the relation between Q and T In other words it is the time-discharge curve from a filter Intregrating D between the corresponding values of T and Q $\int_0^T dT = \frac{R \%}{PK} \int_0^q q dq + \frac{R_m}{P} \int_0^q dq$ or $T = \frac{R \% q^2}{2 PK} + \frac{R_m q}{P}$ . . . "E"

In order to determine the value of Q alone multiply both sides of the equation "E" by $\frac{2 PK}{R \%}$ and add to both sides $\left(\frac{KR_m}{R \%}\right)^2$ This reduces "E" to $q = \sqrt{\frac{2 PKT}{R \%} + \left(\frac{KR_m}{R \%}\right)^2} - \frac{KR_m}{R \%}$ "F."

The temperature has an effect which is taken into account in formula "F." It is only necessary to multiply the expression for Q by the amount representing the viscosity of the liquid under standard conditions and divide it by the expression giving the coefficient of viscosity of the capacity of flow and therefore Q varies inversely as the coefficient of viscosity. If Poiseule's formula for the relation between the coefficient of viscosity and the temperature be used the equation "E" becomes

$$q = \left[\sqrt{\frac{2PKT}{R \%} + \left(\frac{KR_m}{R \%}\right)^2} - \frac{KR_m}{R \%}\right] \frac{\frac{N_s}{N_0}}{1 + at + \beta T^2} \quad \text{. . . "G"}$$

Where N_s = coefficient of viscosity under standard conditions of temperature, say 68° F. and $\frac{N_0}{1 + \alpha t + \beta T^2}$ = Poiseule's expression for the coefficient of viscosity at the temperature T. If the value for N_0, α and β at 20° C. for water be inserted in the formula "G" the equation becomes

$$q = \left[\sqrt{\frac{2PKT}{R\%} + \left(\frac{KR_m}{R\%}\right)^2} - \frac{RK_m}{R\%}\right] (0.556 + 0.0199T + 0.0001193T^2).$$

Two factors might be added to the foregoing to allow for the effect of the squeezing together of non-rigid solids under increased pressure and to take care of the effect of gravity through the agency of settling or sedimentation. In order to prove the truth of this, Sperry then carried on a number of experiments and evolved several new formulas based upon the ones given.

$$\frac{dq}{dT} = \frac{P}{\frac{R\%q}{K} + R_m}$$

From this the discharge formula under constant rate of flow conditions may be derived as follows, if $\frac{dq}{dT}$ = the constant M, $P = \frac{R\%qM}{K} + K_m M$, or if $\frac{2K}{R\%} = W$, $P = \frac{2qM}{W} + \frac{R_m}{M}$, and $Q = \frac{PW}{2M} - \frac{WR_m}{2}$, where Q = flow of liquid, P = pressure, T = time, K = rate of deposition, R = resistance, % = per cent of solids, R_m = resistance of the filter medium. Using the terms W for $\frac{2K}{R\%}$ and N for $\frac{KR_m}{R\%}$ the equation for discharge under constant pressure conditions developed in the first formulas may be expressed as $Q = \sqrt{WPT + N^2} - N$.

From the foregoing it will be seen that filtration depends upon the following; "P" pressure, "T" time of filtering, "K" rate of deposition, "R" resistance of material, "%" per cent of solids present, "R_m" resistance of filter medium, "T" temperature of the mixture.

The theory heretofore given is of course very incomplete and approximate, and there remains a vast amount of experimental work yet to be done along this line.

Still further modifications would be necessary if ultra-filtration were taken up. This kind of filtration is usually described as filtration which is capable of holding back materials of submicroscopic size. The mediums used in the laboratory for this work are usually filtering papers impregnated with collodion and gelatine, the paper being immersed in water, after impregnation, to remove the solvent so the gelatinous nitro-cellulose is left. The permeability of the medium can be regulated within wide limits by choosing the concentration and controlling the removal of the solvent.

The various experiments, theories and laws deducted therefrom, which have been mentioned, bring out numerous practical points which should be borne in mind Some of the most important of these are: (1) as open a filtering medium as possible should be chosen, (2) if possible in any way to control precipitation prior to filtration microscopic examination and experiments should be carried on to determine the best form of precipitation for filtration, (3) in filtering non-rigid solids care must be taken to build up the pressure gradually and uniformly, (4) high pressures do not necessarily give hard, dry cakes, (5) a thin cake offers lower resistance than a heavy one and consequently gives a higher rate of flow, easier washing, and drying, (6) the cake should be as uniform in porosity and thickness as possible in order to get good washing and drying, (7) lack of proper agitation in leaf filters gives pear-shaped cakes and uneven or partial filling of a filter press produces a cake of varying porosity and thickness both of which are undesirable, (8) the higher the temperature the lower will be the viscosity and consequently the greater capacity of the filter.

CHAPTER II

HISTORY OF FILTRATION

A sole inventor is extremely rare and in the opinion of some writers non-existant. The patentee and the one given the credit as the originator is the one who puts the final touch to make the scheme practical. It, therefore, is impossible to say who invented the first filter and all machines must be considered as the practical application of long known principles.

Observation of various processes in nature, such as the purification of water by trickling through sandy soil, or perhaps accidental passage of rain water through outstretched cloth, a garment, or tent cover would obviously suggest the simple expedient. Entomological considerations show that filters were early made of fulled wool or felt, the Latin "filtrum" a filter, being closely connected to "feltrum" felt or compressed wool, and both are connected to the Greek ιπsλ, signifying hair.

References have been found to the manufacture of wine by the Chinese about 2,000 B. C. and it can be assumed that some kind of filtration was here employed. Doubtless some crude methods of filtration were used as far back as among the Cro-Magnon men, since wherever man existed, at certain periods his drinking water must have become turbid, making some method of clarification necessary.

The earliest written record of filtration is that cut on the walls of the tomb of Rameses II, at Thebes, where there is described and illustrated the siphoning off of liquors of various kinds by means of threads. It might be well to state at this point that up until the early part of the nineteenth century there were considered to be two kinds of filtration, that which in reality was capillary siphoning, and ordinary filtration as it is understood to-day.

The earliest book in which reference to filtration could be found was in Plato's "Symposium," and here too capillary siphoning is referred to. This book written in 400 B. C. gives the following, "Socrates then sitting down observed, it would be well Agatho, if wisdom were a thing of such a kind as to flow from the party filled with it to the one who is less so, when they touch each other, like water in vessels by means of a thread of wool from the fuller vessel to the emptier." Aristole, the pupil of Plato, in his essay "De Generatione Ammalia" refers to the other process as follows; "flesh is produced, therefore, through the veins and pores, the nutriment being deduced in the same manner as water through earthen vessels not sufficiently baked."

The ancient Romans used strainers made of a great variety of materials. These strainers were employed mainly for wine and for the wealthy were constructed of silver and bronze, but for the poor were made of linen or other fabric. In Egypt, China, and Rome, the wine filters consisted of bags or colanders in which the grapes were placed and squeezed by means of two poles turned in contrary directions.

Ferdinand Hoefer in his "Histoire de Chemie" states that filtration was first accurately described by Gerber, the Arabian prince and philosopher, who wrote about the eighth century in one of his numerous books, a description of "Distillatio per Filtrum." In this book he states that there are two kinds of filtration; a capillary siphoning, and ordinary filtration by trickling through a filter.

The filtering of water described by Phiny in 77 A. D., by Rhanzes in 930 A. D., by Avicenna in 1020 A. D., by Lulli in 1300 A. D., Libavia in 1500 A. D., etc., all give filtration as a distilling by filtration, in which the water to be filtered is placed in a vessel and a jag of felt or woolen cloth is placed in it, the other end of the jag going over the top of the vessel and reaching to a vessel below, the liquid is thus drawn up by capillarity and discharged by gravity. The advantage of this system of filtration was that, when adjusted, it required no attention, it gave a perfectly clear effluent, and it filtered the solution to the last drop. Its use died out about the middle of the nineteenth century because of its slow and necessarily limited application.

Water clarification and wine filtration were the most important classes of filtering carried on in the middle ages and up to the nineteenth century. Sand filters were used for water clarification and they consisted of earthen pits into which first gravel and then sand was placed. The water was fed in at the top, allowed to percolate through, and drained off at the bottom much like the slow sand filters of to-day. Wine filters were the old bags and perforated plates through which the juice was squeezed as in the days of the Romans. There was a small amount of filtration carried on by alchemists during this period but where sand filters were not used it consisted merely of capillary siphoning or straining with some laboratory filtering through paper as mentioned by Juncher in his "Conspectus Chemiae" published in 1730. Later on the development of the potash beds in Europe necessitated extensive leaching and various gravity filters were brought into use.

In 1591 Federigo Granibelli invented a method of clarifying sewage water from the streets of London but because of lack of interest it never came to anything. This was one of the first recorded inventions for sewage and although many patents were taken out later on, they all followed his idea of sand leaching and it was not until the beginning of the twentieth century that sewage filtration was at all successfully accomplished.

Among the first economically important filtration patents to be taken out that of Cuchet and Montfort in France and that of S. McComb, J. Smith, and B. D. Galpin in America are the ones most commonly known. The filters patented were for the rapid filtration of water and wine and consisted of cloth mediums fitted on frames and suspended in containers. The American patent differed from the French in that the filter container was closed, although nothing was mentioned about pressure being used. Needham, in England, therefore, is usually accredited with obtaining the first filter press patent, in 1828. A little earlier in 1824 Cleveland, an Englishman, took out patents for the clarification of sugar juices through bags and in 1830, Taylor, in America, patented a modification of this method, which filter is still being used by some sugar companies and was used by nearly all up to a few years ago. In these filters the juice is fed through pipes to the various bags and allowed to drain through by gravity, the whole set of bags being enclosed in a container to prevent loss of heat.

After each run the bags have to be removed and cleaned, which of course involves considerable time and labor. In order to increase the rate of flow through the bags J. Kite of Vaux, England, in 1857 invented a method of forcing the juice through the bags by means of a force pump. Danek improved upon this about 1864 when he perfected in Prague a filter similar to the Taylor except that he used rigid iron or wooden frames to prevent the bags from collapsing and employed pressure to force the juice through the bags from the outside inwards, thus reversing the method Taylor used. This same type with a few variations and operated by gravity was started by the Societe Philippe in France and by Karakowsky in Hungary a short time later, really as a result of Jelinek and Fry's method of purification of sugar juices by means of milk of lime and carbon dioxide gas perfected in 1863.

In 1858 Dr. Julius Lowe described a filter using asbestos as a filtering medium which filter could be used in filtering gelatinous and corrosive liquids. In 1860 Professor Bottger employed gun cotton in filtering liquids which acted chemically on paper. In 1867 Dr. Gibbs used powdered glass for a filtering medium. In 1869 Bunson perfected a suction filter and although numerous attempts had heretofore been made to filter by vacuum he was the first to demonstrate its practicability. Gooch's crucible filter perfected in 1878 was a modification of the Bunson suction filter. The development of the potash beds in France brought this method of filtering into prominence as leaching was the main step in manufacturing. Large false-bottomed tanks were used and into these the sludge was charged, the clear liquor being drawn off the bottom by suction. The tanks were operated until the cake or layer of solids was three, four, or more feet thick, when it became necessary because of the lowered rate of flow and lack of room to feed in more sludge, to clean out the accumulated deposit. The only way that this could be done was for men to get into the tanks with shovels and dig it out. The great inconvenience and expense of this method of handling led to several inventions to obtain continuous filtration, those in which a revolving drum was used being the most successful. One of the first of these was that of J. Droeshort of Paris, who in 1893 patented a revolving drum covered with a screen around which passed an endless belt. The belt passed from the drum to rolls where the cake was dried and removed and thence back to the filter drum. The Solvay Company who took out patents in Belgium in 1896 on drain filters and constructed machines which were very successful. Although they used the same drum which had been employed for some years they did not use a travelling belt, but filtered through a medium fastened permanently on the drum, discharging the solids over a scraper as the drum revolved. This same type is still being used by the Solvay Company for the handling of their bicarbonate of soda, both abroad and in this country. In 1903 George Moore patented the multiple compartment rotary filter, which machine allowed separation of wash water from filtrate and the application of compressed air for automatic cleaning. This development made the rotary filter, wherever the slurry was suitable for its use, the most efficient and economical machine which has so far been devised. Modifications of the Moore type now being manufactured are the Glaymorgan Rotory Filter developed in 1915, the Oliver Continuous Filter brought out in 1908, the Portland Continuous Filter brought out in 1912, and the Zenith Rotary Filter which is manufactured under the Moore patents.

It was about this same time that Moore patented his leaf filter which found much application in the cyanide process of extraction, and is often given credit for first making possible the reclaiming of low grade ores and tailings. This filter consisted of leaves connected together and to a common header, submerged in an open tank and operated by suction. It was transferred from one tank to another for washing and discharge by means of an overhead crane and as vacuum connection was by means of rubber tubing it was thus semi-automatic. Butters made these leaves stationary in a tank and washed and discharged by filling and emptying the tank. There were many other filters of the leaf type and Moore construction (differing from the bag filters) brought out about this time and it was not until the United States Circuit of Appeals rendered Moore a favorable decision in 1912 that the basic nature of his apparatus was generally conceded. Shortly after Moore took out his patents, one of his associates, Kelly, enclosed the leaves in a container and operated them under pressure, drawing out the leaves horizontally and in one unit for discharge. This machine because of the cake which could be built up under high pressure is widely used Sweetland about the same time enclosed circular leaves in a clam-shaped filter and discharged by swinging open the lower half of the press and applying air pressure to the interior of the leaves, as is done in the Moore and the Kelly The Burt revolving filter, consisting of leaves fitted to the shape of a cylinder and filtering from the inside outwards, and the Burt cyanide filter, rather similar to the Kelly but with the leaves stationary and the container on an angle, with a moveable head for discharge, were brought out a few years later, as were the Ridgway and Merrill filters.

In 1915 The General Filtration Company brought out a filter of the rotary type in which the drum was constructed of a composition called "Filtros." This machine was particularly designed for acid solutions and is used in many such plants

In 1915, also, Dr. H. B. Faber invented the rotary hopper dewaterer, which machine is manufactured by the Industrial Filtration Corporation. The dewaterer as the name implies is for the dewatering of heavy crystals and is similar to a series of Buchner funnels arranged radially about a central shaft, each connected by a separate pipe line to a multiple valve hub. This machine is largely used in dewatering free filtering solids of a high specific gravity.

In 1916 the United Filters Corporation started making a filter consisting of a series of discs mounted on a central shaft, suspended in an open container, connected to a multiple valve and operated by suction. This machine was for dewatering large quantities of ordinary free filtering solids.

Vallez in 1916 enclosed a series of disc filtering units in a container and employed pressure for filtering. The units were connected to a central valve and revolved during filtration in order to build up a uniform cake. They are especially successful in clarification work.

The filter press as it is known to-day, whether of the recessed plate or of the alternate plate and hollow frame design, is largely a result of the work of John Johnson of England. In the early eighties he devised some filters of the plate and frame type for his own use and these proved so successful that he entered the filter press business. Johnson later came to America and started the John Johnson Filter Company. Shriver and Co. commenced building filter presses a few years later and their most important development is the Atkins-Shriver filter patented in 1918 which is a vertical type press, having arms between each plate that plow off the cake when the plates are revolved. The Sperry, Perrin, Day, Provo, Independent, Merrill, Patterson, Albright-Nell, etc., filters are all more or less alike in general construction, differing in the plate or frame design. These filter presses although expensive to operate, clumsy to handle, and imperfect in their wash, are more used than any other type of filter and in most cases the reason is that no automatic or leaf filter will handle the slurries to be filtered and give equally good results.

The development of water filters is usually considered a separate subject from the filters just described, and although but few types have been developed, water filters have reached a greater state of perfection and standarization than any other filtering apparatus. Sand filters of various construction have been used from time immemorial and they still form the basis for most water filtration. There are usually recognized to be four kinds of water filters; slow sand filters, modified sand filters, mechanical filters, and double sand filters. The slow sand filter is the old type of graduated gravel and sand through which the water percolates, usually known as the English system. The modified sand filter usually has sedimentation tanks before it and is so constructed as to allow back washing for cleansing. The mechan ical filters called the American system, are closed containers holding sand and gravel or other medium for clarifying, and operate by pressure. They are cleaned by back washing and often have sedimentation tanks before them. The first large mechanical filter was installed in the Little Falls Plant of the East Jersey Water Company in 1902. This has proved to be very successful and since then numerous others have been installed. The double sand filter consists, as the name implies, of two sets of filters, usually of the modified sand type. It is not possible to take up here the numerous household and small water filters, except to say that practically all operate under water pressure and use some form of charcoal or paper as a filter medium.

In 1917 an attempt was made to standardize water filters. The two kinds, gravity and pressure, both have beds of coarse sand (except those having beds of coagulants) and the individual makes all give substantially the same rate of flow, so that the only difference is in material and workmanship.

Screens are used in most sewage disposal plants to take out the larger solids. They have been developed almost entirely within the past twenty years, especially abroad. There are four kinds in regular use, disc screens, drum screens, 'horizontal screens and cone screens. Cleaning of the screens is accomplished by means of brushes, back-washing, or a combination of both.

Sprinkling filters, a rather recent innovation, are sprays which take the sewage after screening and Imhoff tank or other sedimentation and throw it in the form of coarse drops over beds of crushed stone, usually several feet in thickness. The effluent which drains off from the crushed stone beds is practically clear and is ordinarily safe to run directly into streams.

Hydraulic presses have been successfully used for the past fifty years to extract oils and juices where ordinary pressure would not give sufficient extraction. There has been little variation made in the general design, all depending upon squeezing between two or more rigid plates. Numerous improvements of course have been made in the actual construction, particularly in applying high pressures.

Oil extractors and moisture expellers are products of the past decade and generally consist of a tapering screw encased in a shell. As the screw moves forward in revolving, the material is carried with it, the liquid being squeezed out at the same time.

Oil filters of various kinds both for filtering the oil itself and for separating oil from water are likewise a development of the last twenty-five or thirty years. Oil filters enable oil to be purified and waste oil to be reclaimed, while separators of oil from water enable exhaust steam to be used and means a saving of coal for the boiler.

Dust collectors, such as the bag-house collector, came into use to save the valuables lost in smelters and coke ovens. The great variety of gas filters, vacuum cleaners, air filters, etc., are a much later development. The invention of the turbo-generator made the filtration of air a necessity, especially during the war and as a result many improvements in filters for this use were made.

There have been numerous machines made within the past thirty years, which although not strictly filters, yet because of their application to this field, deserve mention. The Dorr Classifiers and Thickeners invented in 1904 have found great success in the mining field and recently have been introduced into industrial plants. The Cottrell system of electrical precipitation invented about fifteen years ago has largely surplanted the old bag-house collectors and has enabled fume and smoke nuisances to be eliminated. The use of zeolites for removing the hardness from water and for absorbing oil in water has proven to be very successful recently, although patents were taken out on similar processes a number of years ago; but never attained commercial success.

The foregoing is only a very bare outline of the more important filters most of those of recent development being merely mentioned, but it will give the reader a general idea of the growth of filtration up to the present time. Since there have been granted 3,269 patents on filters and filtering apparatus in this country alone since the opening of the Patent Office, not including centrifuges or special machines, any attempt of this kind at filtration history must necessarily only touch upon the types which seem to have been the most basic and fundamental in filtration development.

CHAPTER III

DEWATERERS, EXPELLERS, FALSE-BOTTOM TANKS, AND CLASSIFIERS

The subject of dewaterers, expellers, false-bottom tanks and classifiers is taken in a broad sense so as to include not only those machines so named, and those designed to handle heavy crystals and high specific gravity solids, but also to include paper mill machines which dewater the paper stock to a desired proportion of stock to water, grain extractors which crush out the moisture from relatively dry grain, etc.

Expellers might properly be named dewaterers as their primary object is to squeeze the water out of semi-fluid or solid mixtures, but in order that they may be properly described and discussed, it is necessary to take their trade designation.

False-bottom tanks are used in many plants and a great deal might be written about them but as they are rather limited in application and inefficient in operation their use (except for water filtration) is dying out. Although there may be times when stationary filters are the best or the only filters which will give satisfaction, these cases are rare and they are not of sufficient importance to be taken up in detail The only stationary filters which need discussion at all are those used for filtering corrosive materials.

Under classifiers the Dorr Classifier is the only one described as this machine is the one which is the most widely used and the most representative of its class. Imhoff Tanks, Boston Tanks, etc., are continuous settling tanks, the speed of settling determining the rate of flow and period of retention in order to get the desired classification.

The Bird-Save-All.—One of the best known save-alls is the Bird-Save-All manufactured by The Bird Machine Company. It is designed to save the stock lost in waste water (known as white water) from paper machines and is used in combination with settling tanks. The machine (Figure 32) is similar in a general way to the single compartment rotary filters described in Chapter XII, but does not attempt to build up a dry cake or operate under high vacuum. The vat of the container is made

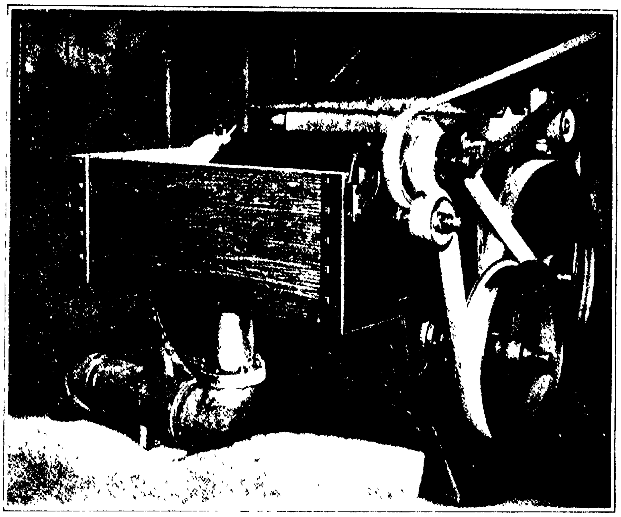


Fig. 32
Bird Save All

of wood, with cast iron ends and the cylinder is of brass sufficiently strong so that no inside spider is needed. The cylinder heads are of heavy cast iron and have hollow journals through which passes the connection to a shower pipe which is placed inside the mould. There is a variable speed drive which automatically regulates the speed of the cylinder to the volume of water, maintaining a constant head outside the cylinder.

In operation the white water enters the vat *B* (Figure 33) through inlet *A* and is strained through cylinder *C* which revolves in the direction shown by the arrow. The water is discharged from the end of the cylinder opposite the drive. The fibre gathered on the mould is driven off as the cylinder revolves by shower *D*, and the recovered stock—a thick mixture of fibre and part of the water from the shower—falls into stock compartment *E*, from which it is returned to the point where it is to be used by the centrifugal pump bolted to the stock compartment. When needed to help the shower clean the wire, brush G may be used but when not in action it can be lifted off as it is placed on adjustable brackets.

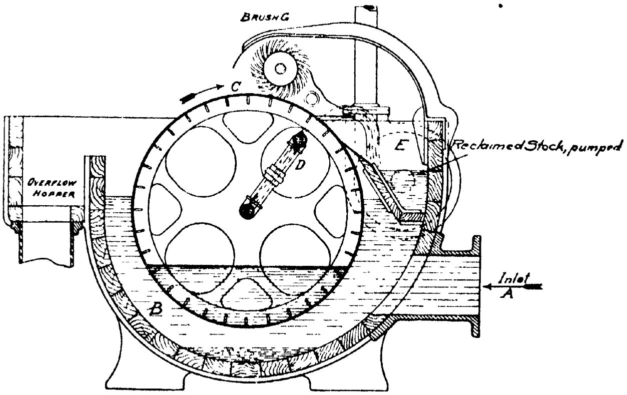


Fig 33
Bird Save All (Section)

The speed of the cylinder varies with the volume and consistency of the white water. This speed is controlled by a float which rises and falls with changes in the head of water outside the cylinder. The float is connected with the variable speed drive.

In case the volume of water exceeds the capacity of the Save-All, it overflows at the outlet which is connected to the main outlet of strained water from the cylinder.

The variable speed drive prevents the head of white water from falling below the horizontal diameter of the cylinder which fall would cause the stock to fall off the cylinder as it emerged into the air. When the water level falls below a predetermined point an idler pulley falls from the link leather belt and the belt will slip, this reduces the speed of the cylinder and if the level continues to fall the cylinder may be stopped altogether. As the accumulation of stock on the mold prevents the free flow of water the level will rise and carry a float upwards and the idler pulley will tighten the belt to the point of driving. The butterfly valve used in connection with the shower pipe is opened and closed by the connecting rod to the idler pulley so that the shower is shut off when the cylinder is not turning.

The machine requires little power for operation, is very simple in construction,and is capable of handling high capacities.

If much clay is present in the water however, the screen, if fine enough to catch all the fibers, becomes clogged very quickly so that the effluent has a high percentage of water as the screen must be constantly cleaned. Also the use of a low head for filtering enables a slight obstruction on the filtering medium to materially cut down the rate of flow and efficiency of the machine.

Oliver Sand Table Filter.—In order to handle coarse and granular products the Oliver Continuous Filter Company build the Oliver Sand Filter. The machine is essentially an annular bed filter, divided into compartments, each of which is connected to an automatic valve. The bed is supported on a heavy central trunnion and revolved by a worm-gear drive. A rail running on a set of rollers maintains the bed in a horizontal position and reduces friction. Figure 34 illustrates the method of discharging the dry cake and shows the general construction of the machine.

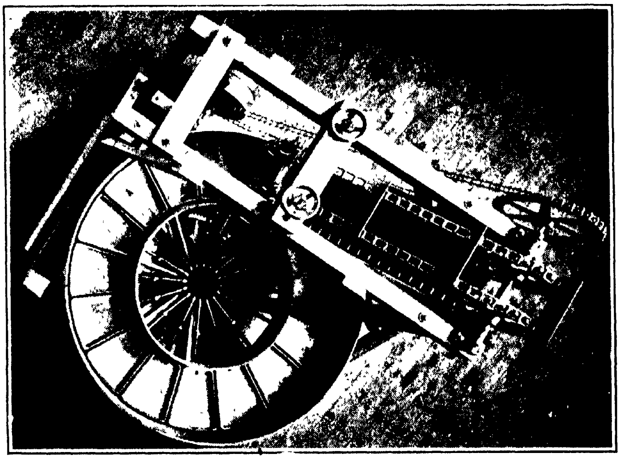


Fig. 34
Oliver Sand Table

The material to be filtered is distributed evenly across the revolving bed at a point immediately behind the elevator. Vacuum is automatically applied to each compartment to remove the liquor and leave the solids on the surface of the filtering medium. Wash water may be applied at any point of the cycle to replace soluble salts or mother liquor and the wash water may be kept separate from the filtrate by means of the valve, as in the rotary filter. A stationary scraper removes the cake which the elevator discharges at a convenient height. This scraper is adjustable but is not allowed to come in contact with the filtering medium.

The most satisfactory results are obtained when the material to be filtered is of a granular nature, any size finer than one-quarter of an inch in diameter, but entirely free from slime or colloidal matter. The machine while usually constructed of cast iron may be made of bronze, lead, copper, etc., for special conditions and the filter medium may be of cotton, wool, metal or tile.

The filter gives continuous and automatic operation and enables the handling of heavy solids which could not be taken care of by means of the rotary filter, leaf type, or plate and frame filter press. It requires little power for operation and discharges a cake with a relatively low moisture content. The method of discharge, however, is rather awkward, great care must be taken in alignment to prevent the scraper from tearing the filter medium and the changing of the cloths is quite a time consumer and expense. There is no means of back washing the cloths satisfactorily and even though free filtering solids are handled it is always desirable to be able to easily clean the filtering medium The fact that no materials containing a small proportion of slime can be filtered limits the application of this machine to a comparatively narrow field.

The Wood's Machine.—The Glen's Falls Machine Works manufacture a machine called the Wood's machine which is used as a pulp thickener, save-all, pulp washer, and water filter. The machine as shown in Figure 35 consists of a cylinder with wire facing, suspended in a container. There is an arrangement of slats on the inside of the cylinder which form pockets and these pockets are filled with water on the rising side. Some of this water discharges outwardly through the facing wire at a point just above the top of the dam, ejecting the stock from the face of the cylinder and forcing it over the dam and into the thickened stock compartment. The dam is adjustable, so that to procure thick stock the dam is kept as high as possible and when thin stock is wanted some of the movable sections of the dam are taken out. The cylinders of the large machine are 48 inches in diameter with a 120-inch face and the smaller ones 48 inches in diameter with an 80-inch face. The cylinder revolves at about seven to ten revolutions per minute and will thicken thirty tons of chemical pulp from one part stock in five hundred water to one part stock in fifty parts water or will save waste from mills producing sixty to ninety tons or will wash thirty tons or will filter water for production of sixty to ninety tons.

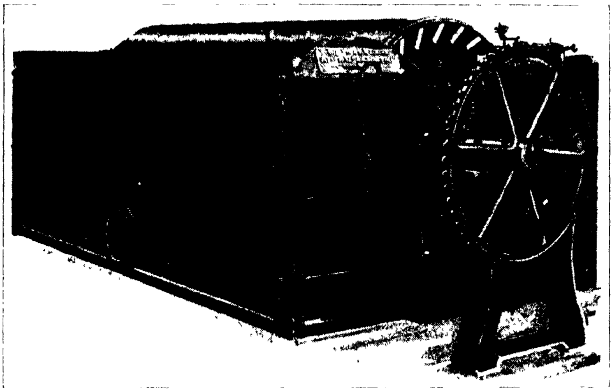


Fig. 35
Wood's Machine

The machine is continuous and automatic, has no scraper or roll for removing solids, requires no suction pump and uses only two horsepower for operation. It has a large capacity and the backwashing keeps the screen clean. As a water filter of course it will only remove leaves, pine needles, and coarse refuse while for washing it requires a good deal of wash water

Zenith Rotary Hopper Dewaterer.—The Zenith Rotary Hopper Dewaterer like other Zenith filters is manufactured by the Industrial Filtration Corporation. The machine was designed to handle salts and heavy crystals which would not adhere to the surface of a filter drum because of their weight. It embodies the same principles as the rotary filter but requires no container and consequently is a cheaper machine to install and operate. Its use however is limited to free filtering solids of a high specific gravity.

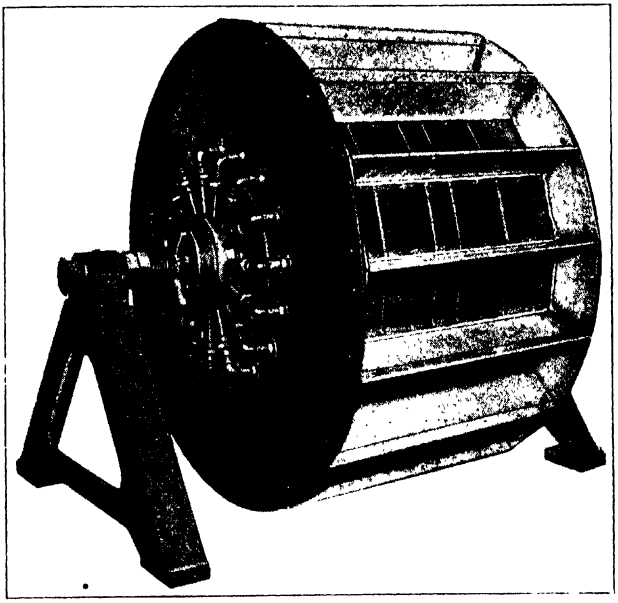


Fig 36
Rotary Hopper Dewaterer

The Rotary Hopper Dewaterer (Figure 36) consists of a series of hoppers or deep compartments with filter bottoms and arranged radially about a central shaft. Each hopper, below the filter bed, is connected to a multiple valve by means of individual pipe lines The design of the valve is such that as the drum rotates suction, pressure, or cut-off is applied automatically to each hopper as it reaches the proper point on the arc. Separation of wash water and mother liquor can also be made should this be desired The machine thus is in reality a series of simple filtering beds, like Buchner funnels, which are connected so as to act continuously and automatically.

As the hoppers rotate they are charged from an overhead chute at about 30° before they reach the vertical. Suction is applied after loading and in the course of filtration each hopper passes through an arc of approximately 120°. Should it be desired to wash the solids, sprays or perforated pipes are used which deliver wash water to the hoppers, at the desired point, as they pass beneath. As each hopper passes somewhat below the horizontal, suction is automatically cut off and the solids, which by this time have been sucked dry, are discharged by their own weight or by means of a puff of air or steam introduced through the valve hub. The discharge may be on a transfer belt or other conveyor situated directly beneath the machine. The arc from the point of discharge to the point of loading is inactive, the valve being blanked off at this point. The entire operation of loading, washing, drying and discharging is automatically taken care of as in the case of the rotary filter described in Chapter XII where the valve is taken up more in detail.

The Zenith Dewaterer is made in various sizes from a small laboratory unit having a 1-foot diameter and a 6-inch face to a machine 8 feet in diameter with a 10-foot face, or even larger in special cases. It may be constructed of acid or alkali resisting materials if desired, as for the handling of copperas or salt. It is adapted particularly to the filtering of such materials as sand, slate, sugar crystals, copperas, coarse salt, and in fact all coarse mesh suspensions.

It has the advantages of continuous and automatic operation and low cost of maintenance. It gives large tonnages and produces a well-washed dry cake Separation can be made of wash water and filtrate and the filter medium is automatically cleaned. On the other hand it can only handle a limited number of materials and the discharged solids while quite dry, do not equal the low moisture content obtained by means of a centrifugal machine.

American Process Company.—The automatic continuous screw press (Figure 37) made by the American Process Company is very similar to that made by V. D Anderson and other companies. The press consists of a horizontal tapered screw built upon a hollow perforated shaft arranged with special stuffing boxes and a movable diaphram so as to allow the admitting of steam to the material to be handled when desired. The screw fits closely inside of a similarly tapered slatted curb and rotates during operation. The gradual decrease in size of the screw and its curbs cause the pressure and as the material cannot turn with the screw or slip on the curb it must move towards the small end of the press as the screw turns. The press is fitted

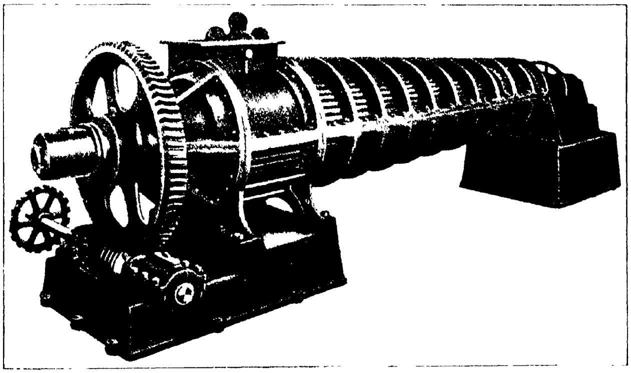


Fig. 37
Continuous Screw Press

at its discharge end with an adjustable cone arrangement, Figure 38, so that the discharge opening can be regulated according to the condition of the material being pressed, and by adjusting this cone any desired pressure may be produced in the press. The drainage is both internal and external, the drainage

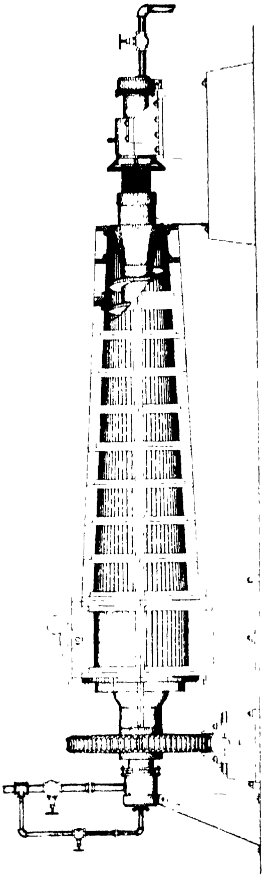


Fig 38

Continuous Screw Press Showing Adjustable Cone area offered by the spaces between the slats of the curb being supplemented by drainage holes in the shaft.

In operation the material to be pressed enters the feeder from a hopper or chute and after being mechanically measured is forced into the straight, purely conveyor portion of the screw. The screw carries it into the tapered curb and it is slowly and positively pressed. Thus the material is continuously fed in at one end and discharged at the other, the liquids are forced out between the slats and into drainage holes of the shaft and conducted to a tank, and the pressed material falls into a screw or other conveyor and is carried away for subsequent treatment.

The machine is of course continuous and automatic which is of great advantage and to this is added the fact that installation and operation costs are low, while the heating of the material by steam enables a high extraction to be obtained of oils and greases. There necessarily must be nothing in the material to be filtered which will interfere with or clog the perforations as these are difficult to clean and the expense of operations runs very high if the machine must be frequently opened and cleaned.

Anderson Moisture Expeller.—The V. D. Anderson Company make a moisture expeller for continuously pressing the free liquor from fibrous material. The machine is used in packing houses for pressing paunch manure so that it may be fed under the boilers for fuel and in glucose plants for pressing the moisture from corn germs and coarse feed preparatory to feeding it into the dryers. The moisture can be removed from a great number of other fibrous materials by this machine and it has had wide application. The usual sizes are machines with cylinders up to twelve inches in diameter.

The expeller is shown in Figure 39 and consists of cast, hinged, slotted casing containing a tapered revolving screw. The stock to be pressed is fed into the hopper, at one end of the expeller, in either a semi-liquid or solid form. The liquid passes through the drainage slots in the cylinder and the pressed stock is forced out at the discharge end, the whole operation being continuous and automatic. The degree of moisture is regulated by means of a follower and hand wheel, while the machine is in operation.

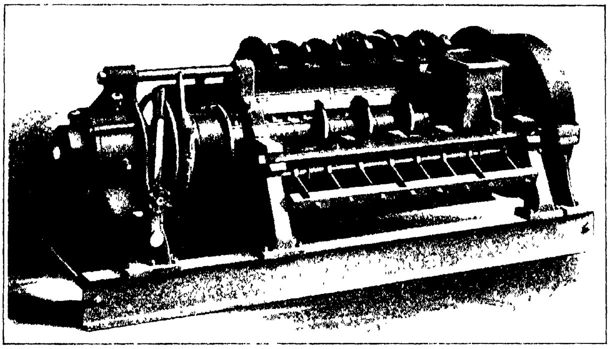


Fig. 39
Anderson Moisture Expeller

The expeller may be constructed of materials to suit the stock to be pressed as a copper-lined cylinder for materials containing acid, etc.

The machine is widely used in its particular field and requires little attention. It is of course not desirable to open the casing frequently as this requires time and labor.

Louisville Continuous Filtering Machine.—The continuous filtering machine made by the Louisville Drying Machinery Company is a grain dewaterer designed in such a way as to hold back the water rather than to squeeze it out, and to allow the grain to go through the rolls. The machine is used a great deal in the dewatering of various grains which are difficult to handle by other means and as the operation is continuous and automatic high efficiency is obtained. The idea of passing the grain through the rolls and holding back the water is to prevent fine material from being lost with the water.

Figure 40 illustrates the general construction of the apparatus which, on account of the great pressure required to hold back the water, is very heavy. The principle made use of is that of a perforated belt passing between sets of rolls. The belt is made endless and in sections hinged together so that as it passes between the rolls it is moved forward by the friction of the rolls and the material On the front and back of the machine are hexagon pulleys and the sections of the filtering belt fit on the side of these pulleys. The lower rolls are put in an adjustable bearing so that any wear can be readily taken up The top rolls are also provided with moveable bearings and tension springs in order to give an even tension and to keep a uniform pressure on the material.

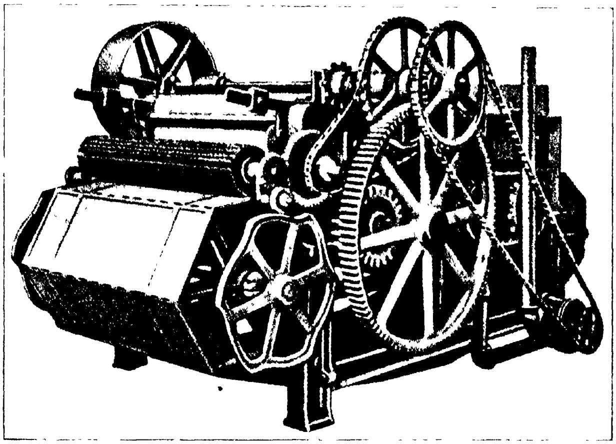


Fig. 10
Louisville Filtering Machine

In operation the wet material is dropped on the belt and carried between the rolls, the water passing through the belt to be caught in a pan placed beneath the lower rolls and above the returning part of the belt, while the solids are passed on over the end of the machine and discharged. The water may be drained from the pan to the sewer and the solids dropped on to a conveyor belt to be carried to the desired point. This makes a very desirable machine for grains, and as it is not enclosed it is open to inspection at all times. Difficulty may be encountered at times by the damming up of the material, uneven riding of the rolls and cleaning of the belt if it should become clogged.

Louisville Continuous Moisture Expellers.—The Louisville Drying Machinery Company also make continuous moisture expellers, Figure 41, which work on the principle of a screw moving the materials forward, with the screw so tapered that the materials will be pressed more tightly together as they go forward towards the end. The machine is made of cast iron and extra heavy to withstand the pressure, and the casting is made in two parts with the entire interior of the machine readily accessible. The casing is lined on the inside with a screen and this screen is backed up with perforated steel plates which permit the water to be drawn off while the bottom of the machine is tapped at several points so as to give freedom for its passage. At the discharge end is a choker which can be so regulated as to give the desired pressure.

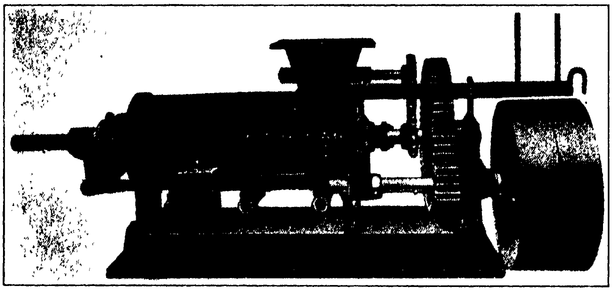


Fig. 41
Continuous Moisture Expeller

In operation the material to be dewatered is fed into the hopper at the end of the machine continuously and the tapered screw moves it forwards and extracts the water by squeezing until the material is discharged at the other end. The water passes through the steel plates and is drained off the bottom thus giving a continuous and automatic operation throughout. The machine is geared so that only one and one-half to three horsepower is required and the capacity, depending upon the material to be handled and other factors, is several tons per hour.

The special feature of freedom of passage of liquor, pressure regulator, and low horsepower requirements are advantages over the usual types of expellers.

False-Bottom Tanks.—Stationary filters and false-bottom tanks are the same in general principle and construction, depending as they do upon gravity for pressure (suction is occasionally used) and a horizontal strainer for separation of the solids from the liquids. This method of filtration is very old and is the kind which is first turned to for a simple straining proposition. Although they are usually slow and imperfect where washing is desired and labor-consuming when they must be cleaned, false-bottom tanks are still used in many industrial plants and stationary filters for small capacities and corrosive materials are also employed in numerous places. The construction usually consists of a tank or vessel with provision for a screen or lattice support near the bottom, so arranged that a filtering bed or filtering medium can be placed over it dividing the vessel or container into two compartments. The material to be filtered is fed into the top compartment and the filtrate is forced through the filtering medium by gravity or by suction. The solids after accumulating to a depth of 2 or 3 feet or more (usually) are sucked or drained, to dry the cake, washed if desired, and then are dug out by hand. This method obviously consumes a good deal of time and labor, while the washing of a cake as thick as several feet is very inefficient, especially where the cake cracks. If, however, the material filters freely as it must to get any capacity out of the apparatus, the filtering medium will last a good while without cleaning and where the solids can be flushed into the sewer there is not much expense to the operation. Many acids are handled in stoneware stationary filters either suction as shown in Figure 42 or gravity, Figure 43, and many chemical concerns use large false-bottom tanks for clarification The sand

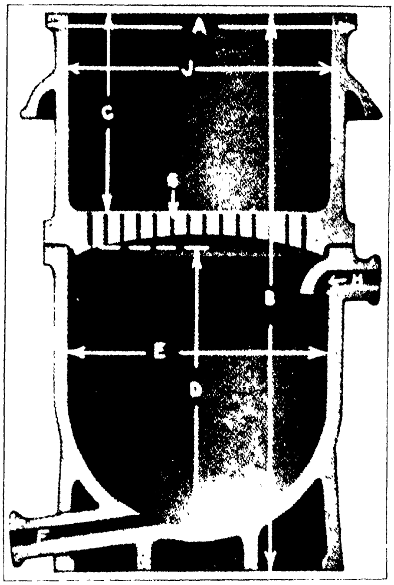


Fig. 42.
Suction Stone Ware Filter.

filters discussed in Chapter IX are false-bottom tanks as in reality are all horizontal filtering devices.

Dorr Apparatus.—The Dorr Classifier was developed to produce a leachable sand which could be removed with a minimum amount of slime-bearing solution and the same principles have been found applicable to a great variety of industries. The apparatus shown in Figure 44 consists of a settling box, in the form of an inclined trough with the upper end open, in which are placed mechanically operated rakes or scrapers for the purpose of removing the quick-settling material from the open end. Each rake is carried by two hangers, one at the sand-discharge end suspended from an arm attachment to a rocker arm or lever, which terminates in a roller. The other depends from a bell crank connected by a rod to the same rocker. The roller is pressed

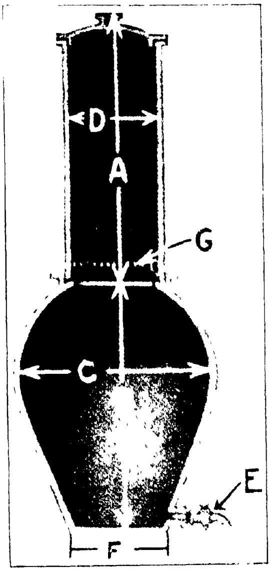


Fig 43
Gravity Stone Ware Filter

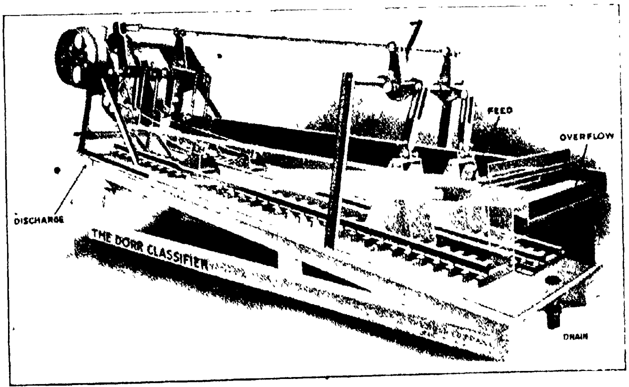


Fig 44
Dorr Classifier

against a cam on the crank shaft. The rakes are lifted and lowered at opposite ends of the stroke by the action of the cams transmitted through the rocker arms and bell cranks, and the horizontal motion is obtained directly from the crank. The bell cranks at the slime end are carried by a second larger bell crank held in position by a chain attached to a spool on a worm gear at the head end of the classifier. By this means the rakes can be raised 10 inches at the lower end and operated in that position or any intermediate one This allows the classifier to be started readily when nearly filled with sand after an unexpected shutdown, and the regulation of the depth of the settling box when in operation to vary the products being made.

The pulp is fed across the settling box and a uniform flow to the lip at the closed end is maintained where the slow-settling solids overflow while the sand or quick settling solids are conveyed along the bottom by the rakes until they emerge from the liquid and are discharged at the open end. The agitation near the bottom of the tank caused by the reciprocating motion of the rakes, assists in keeping the slime in suspension, but is not normally sufficient to cause fine sand to overflow.

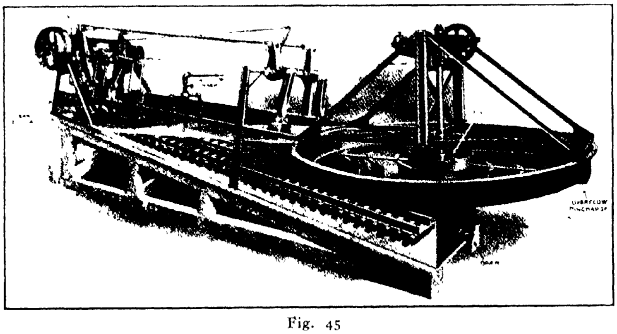


Fig. 45
Dorr Bowl Classifier

The Dorr Bowl Classifier (Figure 45) is particularly adapted for separations at one hundred-mesh and finer, where an absolutely clean sand is required, or where it is desired to produce a finished product all three hundred-mesh or finer. It is also suited to conditions where a relatively large overflow capacity is desired in comparison to the raking capacity.

The Bowl Classifier is a two-stage automatic baffled return classifier. The feed is introduced into the bowl through a shallow feed well at the center. The fines or undersize, overflow the periphery and are carried off by the overflow launder. The sand or oversize is plowed to the center of the bowl and discharged through a comparatively small opening into the main classifier tank and flows underneath the bowl and up through its central opening, counter-current to the sand Usually about 1 ton of back-flow wash per ton of sand is sufficient to entirely separate the finer material.

The Dorr Classifiers are continuous and automatic in operation, require little power and give positive results so that although they occupy a good deal of room and are relatively expensive they have been widely accepted for classification. The main factors controlling the separation between the quick settling solids and the material overflowing are, speed of classifier rakes, dilution, tonnage and slope of classifier. The capacity depends upon the size of the machine and the point at which separation is desired. It will vary from 4 tons to 1,500 tons in 24 hours, as a classifier having a capacity of only 50 to 60 tons overflow per 24 hours when the separation is made at two hundred-mesh may have a capacity of from 300 to 350 tons per 24 hours when separation is made at twenty-eight-mesh.

In the Dorr Multideck Classifier two or more classifier tanks are so connected that the rakes are operated by a single driving mechanism and so arranged that the sandy material is transferred from one tank to the next. Wash water is introduced in the last deck and gravitates from tank to tank in the opposite direction, thus effecting a continuous counter current washing of the sandy material. These machines are built in units with from two to six tanks or decks from 10 inches to 8 feet wide. The length may vary from 20 to 60 feet, depending on the number and length of decks. In cyaniding operations the multideck classifier is used to wash sands or concentrates free from solutions carrying dissolved gold and silver. It has also been applied to leaching copper and zinc ore and pyritic cinders, as well as to the leaching and washing of various ready, quick-settling granular materials, such as sodium nitrate crystals

CHAPTER IV

WATER FILTERS

Gravity and Pressure

The subject of water filtration can only be taken up very briefly in such a volume as this. But, inasmuch as water filters are neither complicated in construction nor radically different in the various designs, the following discussion will enable the reader to obtain a good general knowledge of these machines.

The object of water filtration is clarification and if the water is for drinking, swimming, or similar use, purification in addition. Simple clarification of water by straining has of course been known since the memory of man and the use of coagulants was practiced by the Chinese thousands of years ago, but it was not until 1892 that there came the realization that typhoid fever, cholera, etc., are caused by impure water. This discovery has led to use of ozone, chlorine, or other means of purification in addition to clarification. The purification of water by the use of coagulants will be taken up more fully in the chapter on coagulants.

There may be considered to be two general types of water filters, namely, slow sand filters or the English system and mechanical filters or the American system, the latter using either sand or other material as a filter bed. There are in use in both England and America however, slow sand filters, modified sand filters, mechanical filters and double sand filters. The sprinkling filters having a crushed stone bed and the filter presses using a fabric medium in sewage work might also be mentioned in order to cover the subject fully, although in the case of the latter there are very few in use and therefore they will only be considered generally in the chapter devoted to filter presses.

The most prominent manufacturers of water filters are, The American Water Softener Company, James Beggs and Company, Wm. H. Brey, The Cummings Filter Company, Hungerford and Terry, The International Filter Company, The New York Continental Jewell Filtration Company, the Power Plant Specialty Company, the Pittsburgh Filter and Engineering Company, the

Permutit Company, the Roberts Filter Manufacturing Company, and The Refinite Company.

American Water Softener Company.—The municipal plants of the American Water Softener Company open-gravity type are, as are those of other companies, usually constructed of concrete, as shown in Figure 46, and these plants are equipped with hand-operated valves or with hydraulic or electrically operated valves controlled from an operating table. On the operating tables are mounted pointers and dials for indicating the extent to which any valve is opened or closed, and on these tables are also arranged test basins with cocks for drawing samples of filtered or unfiltered water. On the tables are also placed gauges for showing the air pressure or wash-water pressure, and gauges for indicating and recording the loss of head, an electric alarm forming part of this equipment giving notice when the loss of head has reached a desired maximum and when the filter should be cleaned. If the filters are equipped with effluent rate controllers, gauges are used for indicating the rate of flow through the controllers. A device is attached to the tables for locking all valve controlling levers in position, when once set, so that they cannot be accidentally or intentionally shifted and the operation of the filter disturbed. All gravity filter plants are equipped with effluent rate controllers of either the open or closed type, these controllers being guaranteed to control the delivery of water from the filter with a variation of not to exceed 2 per cent. Gauges of the indicating and recording type show water levels in subsidence basins, filtered water basins and chemical solution tanks, the chemicals being applied automatically and in direct proportion to the volume of water flowing to the subsidence basin or filter.

The open-gravity tank filters in general are made of wood, steel or concrete, the square area and depth depending upon the capacities desired. The filter bed is composed of graduated gravel and sand several feet in thickness and supported upon strainers. Agitating apparatus is often used as illustrated in

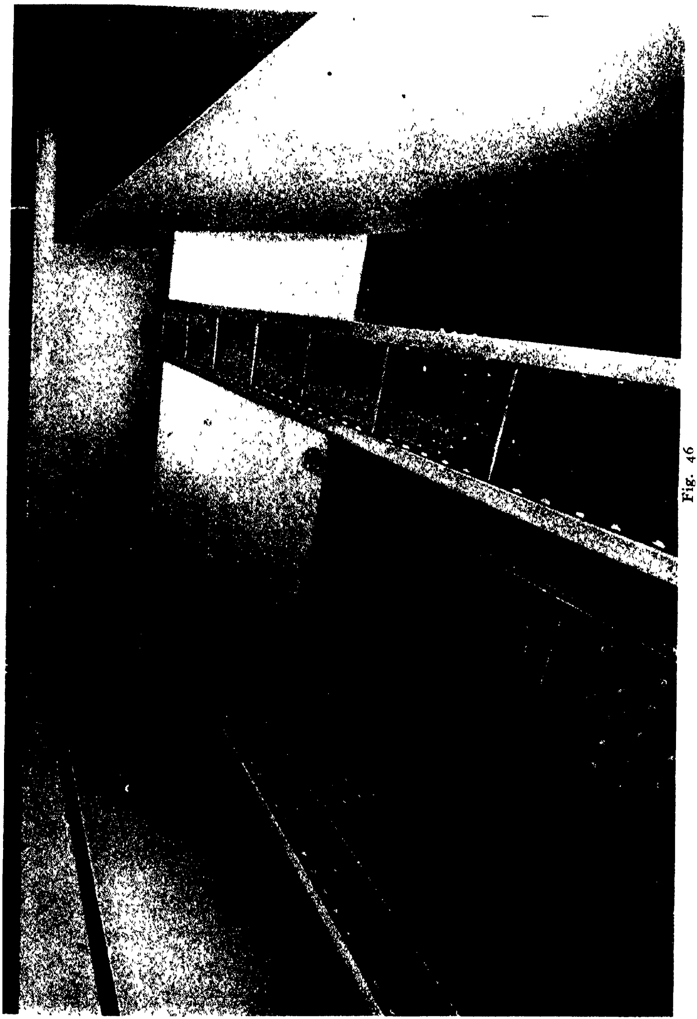


Fig. 46

Interior View of a Filter Unit Showing Wash Troughs and Air and Water Manifolds
Sand Bed Not Yet in Place

Figure 47, the rake-bars traveling in both directions. They assume a perpendicular position and penetrate the sand bed when traveling in one direction and when traveling in the opposite direction they are automatically withdrawn by the action of the sand-bed upon them until their free ends rest upon the surface of the sand-bed. In this way water cannot follow the sand-rakes through the sand layer, form channels, and only be partially filtered. Preliminary subsidence basins which are very necessary in the filtration of turbid water need to be carefully designed and baffle walls used with discretion, as too many walls cause high velocities and are worse than none at all. The travel of the coagulated water in a uniform horizontal plane through the basin should be kept within well defined limits which are influenced largely by the nature of the suspended particles.

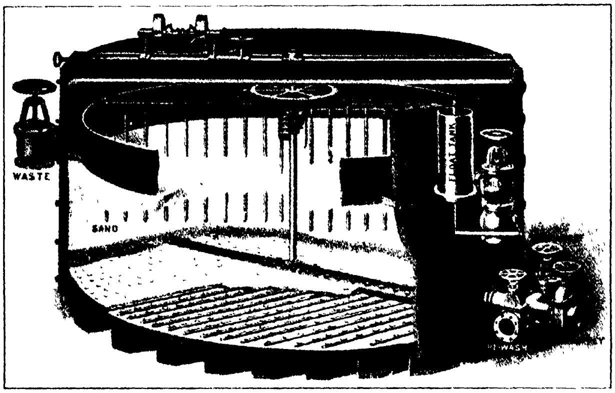


Fig. 47
The Hodkinson Wood Tank, Open Gravity Filter

Filtration plants should be specially designed to meet the particular conditions and requirements of each case, as convenience of the arrangement, character of water to be treated, necessary period of preliminary subsidence, application of coagulents, best coagulent to use, filtered water storage capacity, and other considerations have an important bearing on the proper design of an efficient system, as well as on economical first cost and low operating expense. Where the filters cannot be located so that the water will flow to them by gravity, a centrifugal pump must be used. In paper mills and industrial establishments the suction of the centrifugal pump is often directly connected with the outlet of the filters, water being delivered by the pump directly into the distribution pipe system or into elevated tanks. Otherwise the filtered water is delivered to tanks immediately below the filter.

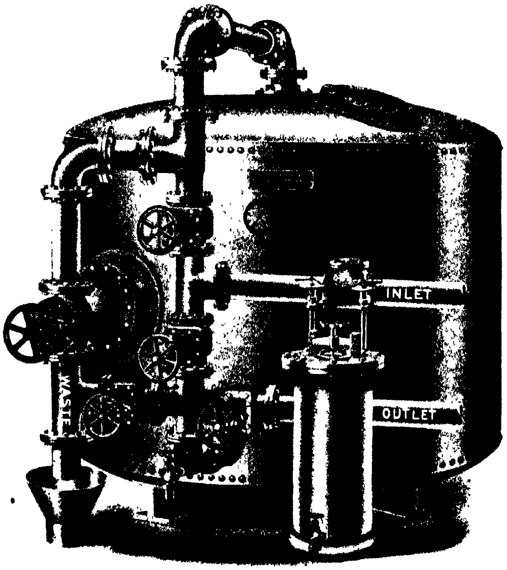
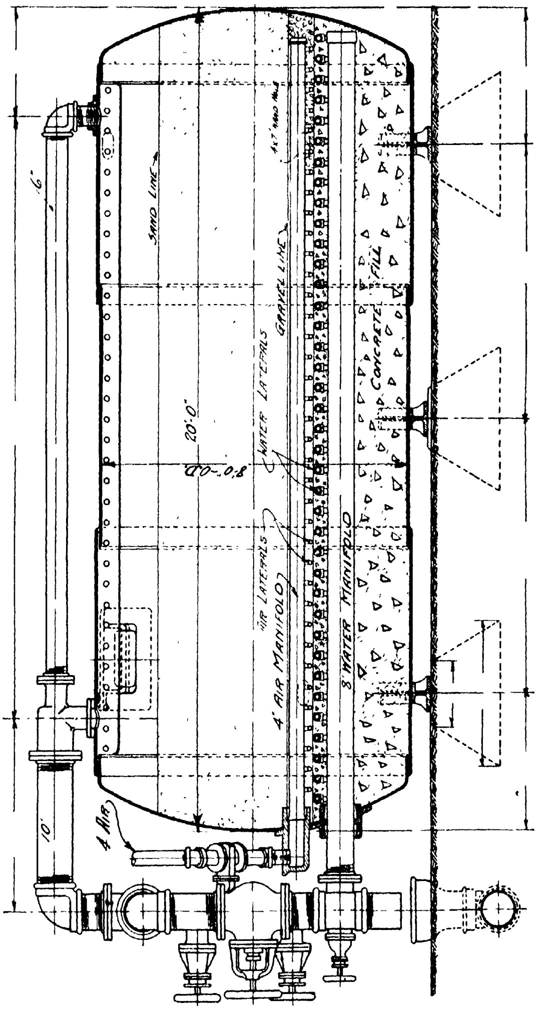


Fig. 48
Vertical Type, Steel Tank, Pressure Filter

Open gravity filters of all types are adapted to filtration of any water supply, and are installed extensively for water works, paper and textile mills, public or private institutions, etc.



SECTIONAL VIEW OF HORIZONTAL PRESSURE FILTER
Fig 49

Pressure water filters are made in two forms, vertical and horizontal, the former being used in comparatively small plants and the latter for municipal works and large industrial plants. The construction of the vertical type is shown in Figure 48 and that of the horizontal type in Figure 49. The strainers or sand valves are of heavy brass, have no sawed slots and are devoid of wire gauze or thin perforated metal. The bottom of the filter below the strainer system is filled with concrete so as to make a level floor. The filtering material is screened washed and graded sand and gravel. A gravel layer one foot thick is placed immediately over the strainers and on top of this a 30-inch bed of sand.

In filtering the water enters at the top of the filter and passes downward through the bed of the filtering medium. In washing the current is reversed, water entering at the bottom and passing upwards through the filter media is carried to the sewer, the filter medium being agitated, scoured and rinsed. This washing operation is repeated about once every 24 hours and occupies about five minutes time, while the bed has only to be renewed once in five or six years

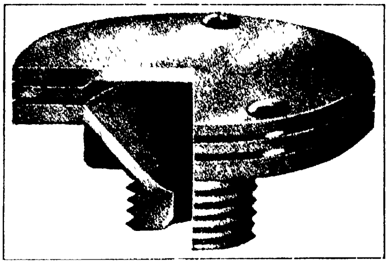


Fig 50
Strainer or Sand Valve

In clarifying and purifying water these filters without a coagulent remove only such suspended matter as is larger than the voids between the sand grains. In treating muddy and impure water therefore alum is used as a coagulent. A feed tank is supplied which automatically adds alum water drop by drop to the main volume of water on its way to the filter through the inlet pipe.

One of the most important parts of a filter is the construction of the strainer or outlet system which serves the twofold purpose of collecting and carrying off the filtered water without escape of sand and of supplying wash-water for cleansing the sand-layer. The efficiency of the filter and economy in the use of wash-water are almost wholly dependent upon this part of a filtering apparatus. In operation the water passes up through the strainer and out horizontally so that there is no danger of the sand settling back and clogging the valve.

The Blackburn-Smith Feed Water Filter.—James Beggs and Company manufacture The Blackburn-Smith Feed Water Filter which machine is made particularly for the removal of organic matter, sediment, etc., from boiler feed water in power plants. This is shown in Figure 51.

Spring, well, river or city water used for feed purposes in power plants frequently contains both chemically combined elements and finely divided particles of clay, sand and organic matter held in mechanical suspension, all of which are injurious to boilers.

Chemically combined elements may be precipitated by treatment in tanks or in combined heaters and purifiers, after which the precipitate should be removed by filtration.

Some sand and other sediment will fall to the bottom of the settling tanks, but clay and other finely divided matter remain in mechanical suspension, and if allowed to enter the boiler, bake on its surfaces and impair the efficiency of heat transmission.

Internal corrosion, whether it be uniform or occurs as pitting or grooving, is very destructive. It shortens the life of the boiler by eating away the plates, stay bolts and rivet heads, and if not checked is apt to result in dangerous explosions. Organic matter contained in sewage or in the water from swamps, peat bogs, etc., often becomes highly corrosive on heating, and also causes foaming, which makes it difficult to determine the exact level of the water, and may therefore lead to the burning of tubes and plates. It may also cause the boilers to prime, and the engine may be wrecked by water carried over to the cylinder.

The methods of treating feed water may be roughly divided into two classes, internal and external; that is, inside of the boiler and outside of the boiler.

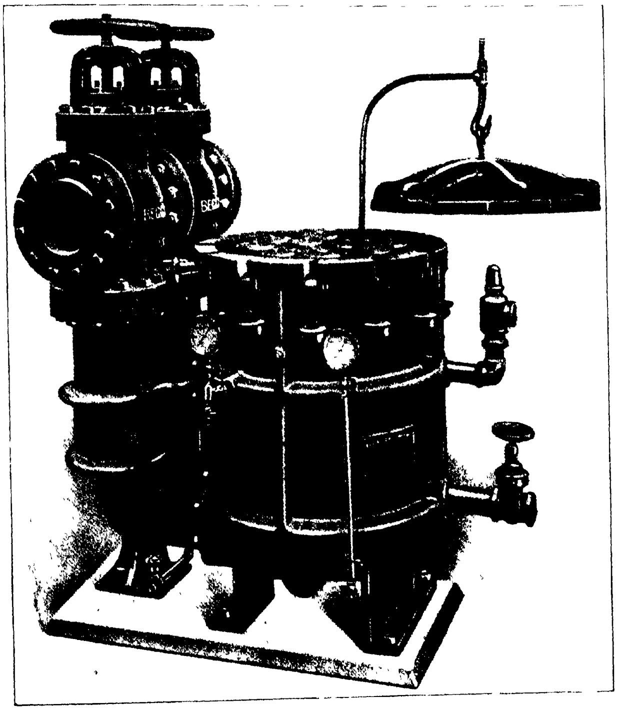


Fig 51
Blackburn-Smith Feed Water Filter

The internal method of treatment is to introduce periodically into the boiler some chemical to change the chemical composition of the scale-forming material, making a precipitate which may be scraped or blown out.

Such boiler compounds, as they are called, may prevent the formation of hard scale, but the impurities as well as the solid matter generally present in the compounds themselves, still remain in the boiler.

As a general rule a boiler is one of the worst possible places in which to carry on chemical reaction, since it nearly always causes more or less corrosion of the metal and is liable to cause dangerous explosions.

The principal ingredients used in boiler compounds are carbonate of soda and tannin, to which are often added adulterants, as coloring matters, etc., which conceal the real nature of the compounds and are added for commercial reasons. Tannic acid attacks and corrodes the steel as well as the scale. Ordinary ink is a solution of iron and tannic acid

There are, of course, plants where the internal treatment of feed water is an enforced necessity, owing to surrounding conditions or lack of funds necessary to install apparatus for external treatment, but it should be avoided wherever possible.

Feed water may be purified outside of the boiler by heating, chemical treatment, settling and filtration.

The first two methods render certain elements insoluble, so that they are precipitated, after which they may be removed from the water by settling and filtration.

Settling or sedimentation removes only the mud and sand which have been carried along by the current and this method is effective only if the water is run into very large tanks and the mud allowed to sink to the bottom by gravitation. It is, therefore, impractical in large plants, since tanks to give ample water supply would be so large that their size would be prohibitive.

If mud, sand and organic matter contained in the feed water are to be removed rapidly to furnish large quantities of water, filtration is essential.

In the Blackburn-Smith feed water filter, Figure 52, filtration is through a double set of cylinders, one inside the other and each covered with a cloth filter medium. The cylinders are called cartridges and are enclosed in a container. The cover of the

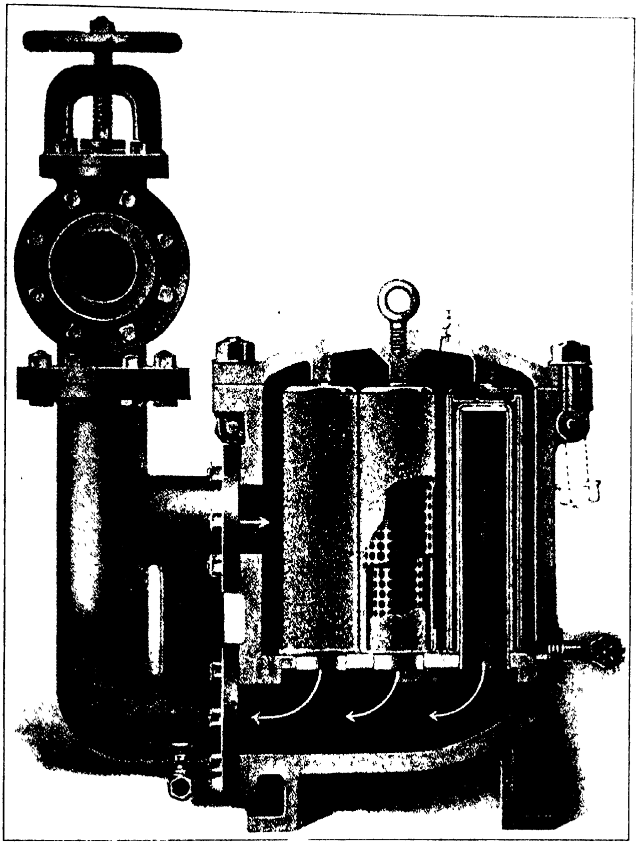


Fig. 52
Blackburn-Smith Feed Water Filter

container is fastened to the body by swing-bolts, and the joint is made by a copper asbestos gasket held in a groove and secured by a tongue on the cover. The filter is tested to a hydraulic pressure of 400 pounds to the square inch.

The number of cartridges in each filter varies with the size of the unit. Each cartridge, Figure 53, consists of two concentric cylinders of heavy brass covered with linen Terry. The lower end of the inner cylinder is rigidly and permanently fastened into the partition which separates the filtering and outlet chambers. The upper end is covered by a perforated brass cap. The filtering medium conforms to the shape of the cartridge, the closed end being drawn down to a nice fit over the inner cylinder, reversed over the outer cylinder, and the other end tucked in and clamped by a brass cap. The bottom end of each outer cylinder rests on a finished surface, and all of the outer cylinders are held in place at the upper end by projections from the under side of the main cover, which press upon the caps when the cover is bolted into place.

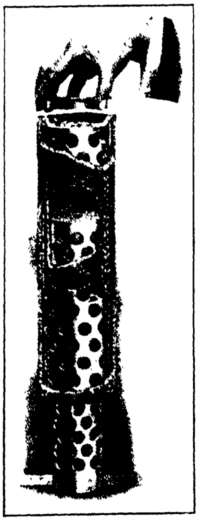


Fig 53
Blackburn Smith Filter Cartridge

Referring to the cross section Figure 52, the filter chest is seen to be divided by a partition into two chambers, water entering through the inlet to the upper or filtering chamber and passing to the lower or outlet chamber through the filtering cartridges set in the partition, and then through the outlet to the feed line. The water passes through these cartridges with little friction, but in the course of time as foreign matter accumulates on the filtering material some resistance will result, as is shown by the readings of pressure gauges connected to the filtering and outlet chambers. A water relief valve automatically prevents the building of excessive pressure in the pump discharge line.

The filter is put into operation by turning the hand wheels on both inlet and outlet valves to their upper limits. When these two wheels are turned to their lower limits the filter is by-passed. It should be noted that the by-pass and main valves are wholly within the feed line and that the filter body and valve connection pipe may be disconnected close to the valves. It is thus possible to remove almost the whole filter without shutting down the plant and without disturbing the feed line It will be seen from Figure 51 that both the main valves are in a straight line with the feed pipe. This is of advantage in installing the filter in plants which are already in operation, as it may be cut into the line at any desirable point without necessitating any change in the piping.

There are times when it is unnecessary to cut out the filter for cleaning, since a portion of the deposits on the walls of the filter chamber and on the outer surface of the filter cloth may be removed by manipulation of its valves Matter which may have been forced into the cloth may be partially ejected by reversing the flow, which also is accomplished by manipulation of valves If sufficient impurities are not thus removed to reduce the pressure difference as shown by the gauges, the filter should be cleaned by removing the foul and inserting the spare cylinders. The cloth will last for a long time if properly washed, and when worn out may be replaced at small cost.

The filter will give high capacities and a clear effluent at once, it occupies a small space and can be inserted in a main easily. It operates without complication of valves and there is no danger of channeling at a high pressure so as to give a cloudy effluent. Double filtration is compelled through two separate filtering surfaces and the filter medium when clogged can be readily changed. The filter possesses the disadvantage however that it is necessary to remove the cartridges for cleaning, as back washing will not continue to suffice. If solids are encountered which tend to clog the filtering medium quickly a great deal of labor will be consumed in changing cloths The expense of these new cloths is high especially when compared with sand filters whose beds last six or seven years without changing and which beds can be thoroughly cleaned by agitation and backwashing.

The Cummings Filter.—The Cummings Filter is manufactured and sold by The Cummings Filter Company. It is designed for purifying water for corporations and industries and utilizes bone-black as a filtering medium. The filters are made in three styles, "D," "H," and "G," the first being for residences and buildings that require a capacity of filtered water from 250 to 1,500 gallons per hour, the second is for buildings that require a capacity of from 2,500 to 5,000 gallons per hour, and the third is for buildings which require 2,500 to 15,000 gallons per hour. Larger sizes of type "G" can be furnished where desired

In type "D," Figure 54, there is a special manipulator used, illustrated in Figure 55, which is the only one employed in operating the filter. When the manipulator is turned so that the figure "0" is opposite the arrow, the filter is cut out, and the water passes to the building without going through it. When the figure "2" is opposite the arrow, the water divides and filters equally through both cylinders. When figures "4L" or "4R" are opposite the arrow, the water filters through one cylinder and

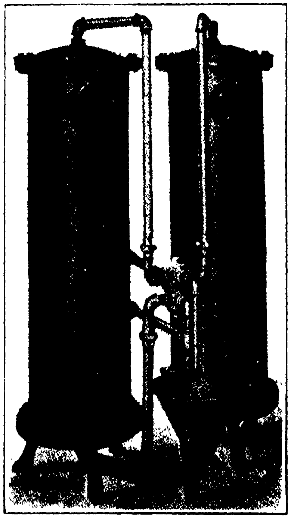


Fig 54
Cummings Filter "D"

then refilters through the other cylinder. When figures "3L" or "3R" are opposite the arrow, the water is filtered through one cylinder, and washes the other cylinder without interrupting

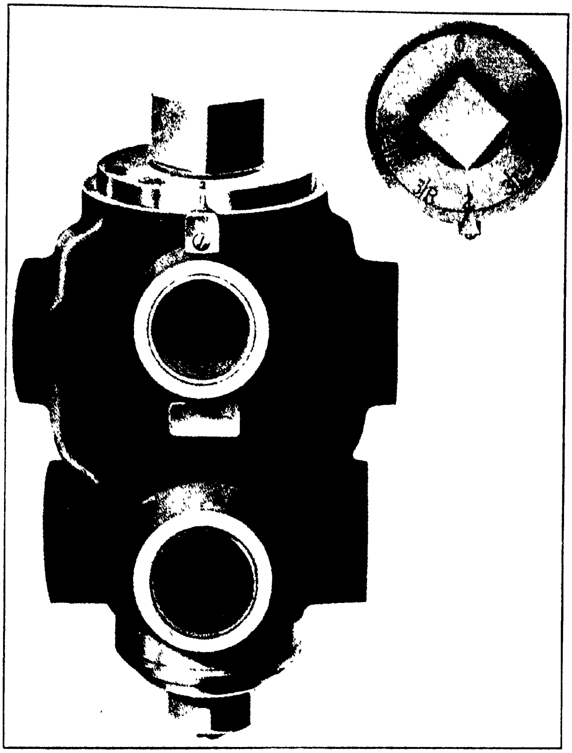


Fig. 55
Cummings Manipulator

the supply of filtered water to the building; in this manner each cylinder is washed separately with filtered water from the other cylinder.

The filter consists of two cylinders, connected by one operating valve. The cylinder, tops, bottom, and legs are made of charcoal iron and are sufficiently heavy to withstand 125 pounds water pressure. All pipes, valves and fittings are made of brass, the diaphragms in the top of the filter are composed of a cast iron ring, to the bottom of which ring is bolted a perforated plate, having over it a circle of brass wire cloth. The ring is tightly packed with sea gravel, on top of the gravel is a disc of hard brass wire cloth and over all is bolted a top perforated plate extending over the cast iron ring 1 inch, and between the

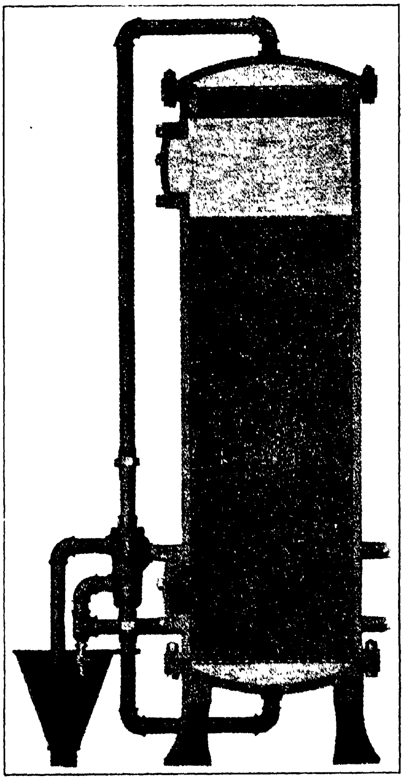


Fig 56
Cummings Filter (Section)

flanges of the cylinder and head, which holds the diaphragm in place, Figure 56. The gravel diaphragms not only hold the filtering bed within the cylinder but act as a strainer as well, keeping the coarse sediment out of the filter, which greatly aids in the process of washing. The diaphragms in the bottom of the filter consist of two perforated plates, with a disc of hard brass wire cloth between the plates. These plates are bolted together the bottom plate extending 1 inch between the flanges of the cylinder and bottom head which holds the diaphragms in place

Style "H" filter consists of two cylinders also, but connected by a system of piping and valves as shown in Figure 57. These

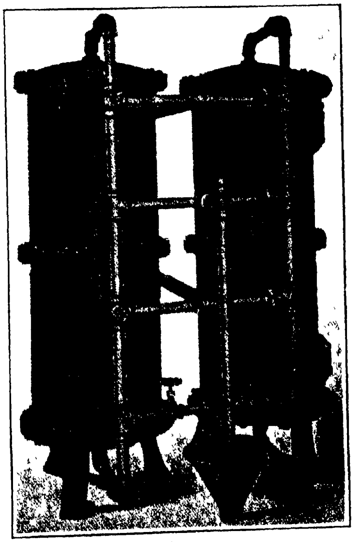


Fig 57
Cummings Filter "H"

cylinders will, like style "D" withstand 125 pounds water pressure and are made of cast iron. They are made in sections to expedite handling and in the top of each cylinder is a gravel diaphragm, consisting of a cast iron ring bolted and covered as before described. The same diaphragms as in "D" are also used in the bottom of the cylinders. All pipes and fittings are of galvanized iron unless otherwise specified. The system of washing can here be accomplished without the use of the valve manipulator and the same results obtained.

Style "G," Figure 58, except that it is made of boiler plate, is similar to style "H" and is made in a large size to handle higher capacities.

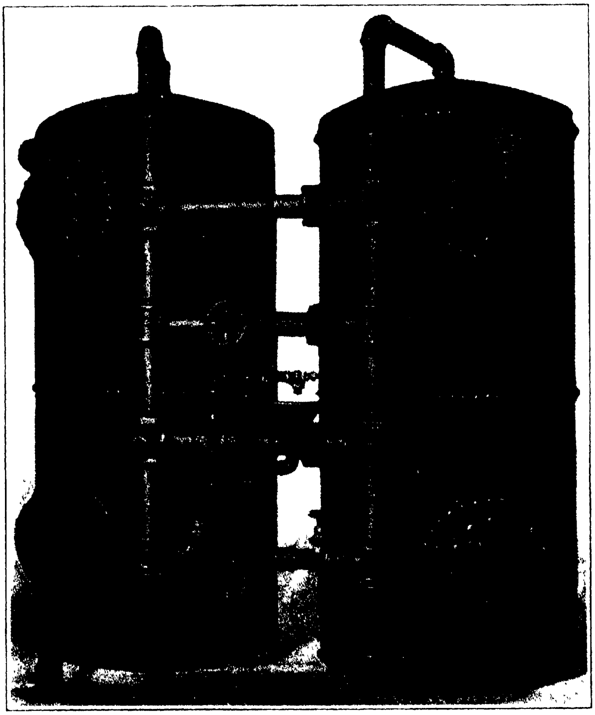


Fig. 58
Cummings Filter—Style "G"

The charcoal filter medium used is all animal charcoal or boneblack and as such is a purifying as well as clarifying agent and is buoyant and easy to clean. Inasmuch as the interstices are very small as compared with sand filters a much finer separation is here made unless a coagulent is used in connection with the sand apparatus.

The Cummings Filter is designed to remove dirt, color, odor, and taste from water and is adapted to residences and small industrial establishments.

Hungerford and Terry.—The filters made by Hungerford and Terry are for the purification of water for industrial purposes and consist of the usual horizontal and vertical pressure, and gravity types with sand as the filter bed and with air or mechanical rakes or both for the back-washing process. The machines are built in sizes ranging in capacity from 120,000 gallons per day of 24 hours to 1,000,000 gallons for the same period. Inasmuch as other filters of similar design and construction are gone into in detail later on the only special feature which need be taken up here is the strainer used. The sand valves, Figure 59, or strainers are made of twelve-guage spring brass and have a one-quarter inch outlet for the filtered water and ports or slots for entrance of the water one-fortieth of an inch in width or finer according to the

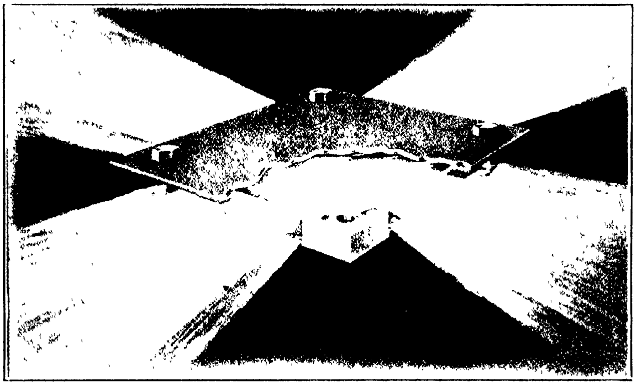


Fig 59
Sand Valve

sand used. The valve is so constructed that the internal pressure of the wash-water causes the side walls of the valve to bend outward slightly, but on ceasing the wash they return to their normal position. As the ports lie between the side walls and the top and bottom plates, any substance that may be lodged in the ports is subjected to a grinding motion which carries it through. If, as is often the case when washing with unfiltered water, a considerable amount of matter is carried into the ports, the increased pressure causes the top and bottom plates to bend slightly, thus proportionally widening the ports and permitting the immediate discharge of the obstruction which is the valuable feature of the strainer.

International Filter Company.—The International Filter Company makes water filters for practically all purposes. Their filters are divided into four general types, as follows. International Vertical Filters, International Horizontal Filters, International Disk Filters, and International Gravity Filters.

The vertical filters range in size from 12 inches to 96 inches in diameter and are used for homes, drinking water systems, swimming pools, and general industrial purposes They may be used singly, in pairs, or in batteries of three or more. In sizes 12 to 24 inches in diameter the filter is built of cast iron and is suitable for ordinary pressures of 65 to 100 pounds per square inch, although tested under a hydrostatic internal pressure 50 per cent greater. The external pipes and fittings are galvanized and separate brass control valves are used. Sizes larger than 24 inches are built of steel with the seams hot-riveted and caulked The filter bed is composed of washed, graded silica filter sand which rests upon layers of gravel. The water enters the filter through an opening on the side near the top. The incoming water is carried to the center of the filter and deflected upwards so that the filter bed is not disturbed, as illustrated in Figure 60. The water then passes down through the filter bed and the filtrate is collected in a strainer or sand-valve system covering the entire bottom of the filter. From here the filter water passes to the filter outlet. In washing, the water passes upwards from the bottom, being distributed by a strainer system, and it is carried off at the top through a wash trough. The upper edge of the wash-water collector is high enough to prevent the escape of sand but low enough to allow the sediment to pass off readily to the drain. The use of two gauges indicates the loss of head and the necessity for cleaning. One gauge is on the incoming side and the other on the outgoing and the clogging of the bed is indicated by the difference in the reading of the two gauges. When this difference is about 5 pounds it is advisable to wash the filter.

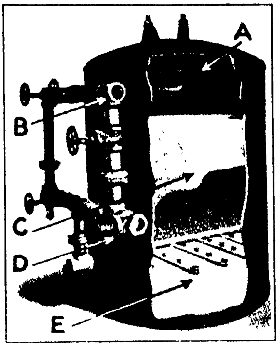


Fig. 60.
Sectional View International Filter.
A, Deflector, B, Inlet, C, Sand, D, Gravel, E, Strainer.

The horizontal filters are all constructed of steel with cast-iron flanged valves and fittings. The controlling valves may be arranged for operation from the floor by hand or by hydraulic power and rate of flow controllers and indicators may be used. The general form of the filter bed, etc., is the same as in the vertical type, while the cycle of operation is likewise similar. Only two valves are needed to operate a battery of three filters and sight glasses indicate when the filter is washed clean.

Filters of both the vertical and the horizontal type often require preliminary sedimentation or coagulation. For this purpose special apparatus is manufactured by the individual companies to go with their own machines although all are very similar in design.

The International Disk Filter is used for comparatively clean water, to remove minute particles of suspended matter. Many of these particles are invisible, but in manufacturing, these fine particles often affect the final product, and for drinking water it is always desirable to remove them. The filter, as illustrated, Figure 61, consists of two circular cast shells, between which the filter disks are held. These disks are locked evenly all around the outer edge by means of quick-operating hinged hand-bolts, which are attached to the lower shell and engage slotted lugs on the upper shell. The filter is made in two styles, one of bronze block tinned throughout, and the other cast iron double galvanized. The fittings of both styles are heavy polished brass. The inlet is in the lower shell and the outlet in the upper and operation is by gravity. When a disk, Figure 62, becomes clogged it is removed and thrown away as it is of cheap com-

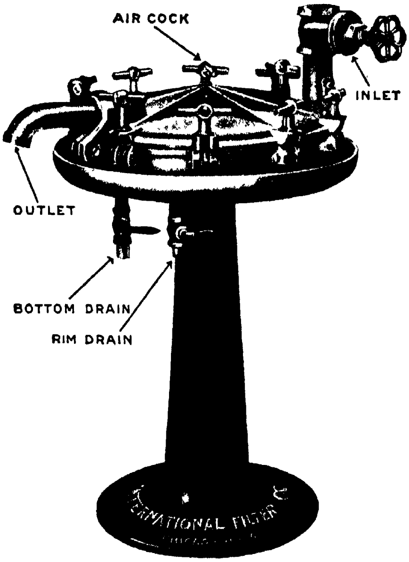


Fig. 61
Disc Filter

pressed cotton fiber. The disks extend to the very edge of the filter shell so that they form their own gaskets and thus simplify the machine. A number of the filters may be connected together and they thereby give sufficient capacity.

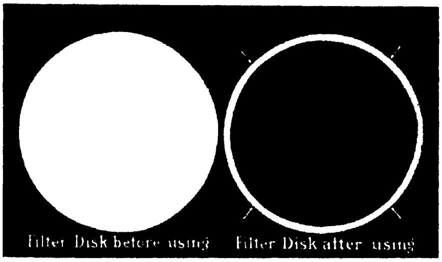


Fig. 62

The gravity filters of the International type do not differ radically from those of other makes and as some of these are taken up rather at length no discussion will here be made of this type.

The New York Continental Jewell Filtration Company.—The New York Continental Jewell Filtration Company is one of the largest companies in the water filter business and as such it specializes in a great number of styles of filters. Their machines are divided into the two general types of mechanical filters, gravity and pressure. Of the former there are the following styles: The New York Sectional Wash Gravity Filter, The Continental Gravity Filter, The Modified Jewell Filter, The Jewell Gravity Filter, The High-Type Jewell Gravity Filter, The Low-Type Jewell Filter, and The Warren Gravity Filter, and of the latter, The New York House Filter, The New York Sectional Wash Vertical Pressure Filter, The New York Sectional Wash Horizontal Pressure Filter, The Continental Double Cylinder Single Valve Filter, The Continental Single Cylinder Filter, The Continental Horizontal Pressure Filter, The Jewell Vertical Pressure Filter, and The Jewell Horizontal Pressure Filter.

Originally the gravity filters were of wooden construction and a few even for municipal plants are still so made as they may be readily added to, taken down, or moved. In general, however, they are made of steel or reinforced concrete although the original design is largely adhered to. This is because any gravity filter is an open tank in which the sand bed is contained arranged above a strainer system and the water to be purified passes through the sand bed by gravity, usually after preliminary sedimentation, into a clear water well. The New York Sectional Wash Gravity Filter, Figure 63, has as its distinguishing feature the sectional arrangement of the strainer system whereby the water used in washing is diverted through one of the valves into one of the several sections of the strainer system so that the incoming wash water may act upon one section at a time with greater velocity than would be the case where the entire strainer system was affected by the same amount of water. This method of washing is often as satisfactory as the more direct attrition furnished by the use of rakes or air and it is cheaper to install and operate.

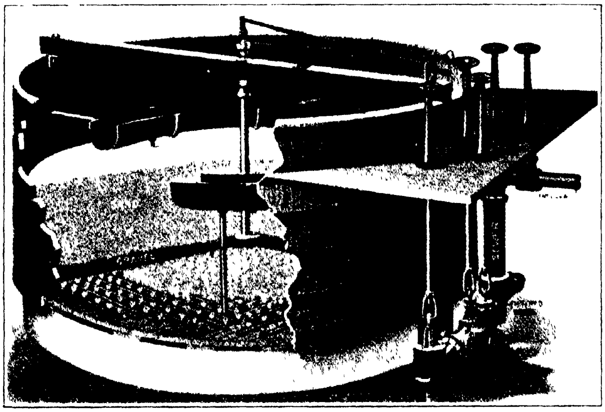


Fig. 63
New York Sectional Wash Filter

The Continental Gravity Filter has the strainer system of the Little Falls or "Williamson" type, trapped so as to admit air under pressure within the header and manifold pipes during washing The air being furnished through a blower or compressor it is forced upward through the strainer system and perforates the filter bed equidistantly and under equal pressure, affording openings through the bed into which the reversed stream of wash water follows, reaching all portions of the filter bed evenly, removing the impurities lodged upon the bed and within it, flushing the impurities to the sewer opening and leaving the filter bed clean again for a new cycle

The necessity of a blower or compressor in connection with this method limits its use, so far as economy is concerned, to cases where a number of units are necessary, as the first cost of the blower increases the cost of one unit out of proportion

The Modified Jewell Filter is constructed with a single tank and wash water gutters are attached to the side of the tank, doing away with the necessity of having two tanks, one within the other, as in the Jewell Filter It is provided with the iron rakes to assist in the breaking up of the sand bed during the washing operation This filter can be furnished at a less cost than the Jewell Gravity Filter and in many cases can be used to do the same work.

The Jewell Gravity Filter is equipped with the agitator or reversible rake used in breaking up the bed during the washing period. While the reversed stream of water is forced upward through the strainer system, lifting and permeating the filter bed of sand and gravel, the rakes are revolved through the sand bed at the same time, thus subjecting the bed to the double action of the agitator and the wash water, cleansing the bed and flushing out the impurities to the sewer In the Jewell Gravity Filter the double tank construction is adhered to, the space between the outer and inner tank being utilized as an annular trough to carry away the wash water in the manner of a weir. While filtering, this same space is employed to distribute the influent water evenly over the filter bed with the least disturbance possible.

The High-type Jewell Gravity Filter, Figure 64, is superimposed above a settling tank upon the same floor space and is very convenient and efficient for moderately turbid waters at low cost of installation.

The Low-type Jewell Filter is arranged generally in conjunction with independent sedimentation tanks.

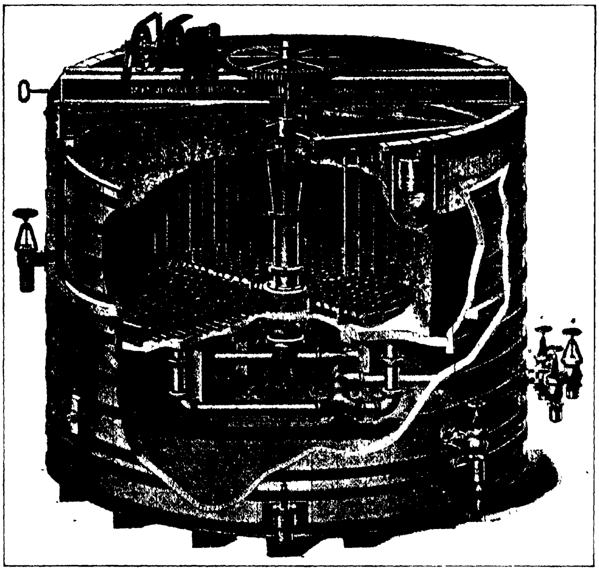


Fig 64
Jewell Gravity Filter

All of the above described types of filters are controlled by controllers of either the "Weston" or "Venturi" type, as may be selected, arranged with the "down-draft" extension into the clear well, enabling the plant to increase its capacity automatically during any abnormal condition such as would be caused by a fire of unusual size and duration.

The Warren Gravity Filter, Figure 65,, is especially adapted to conditions where very little head is obtainable for operation.

In connection with a weir tank it operates under a head as low as 20 inches, the weir tank furnishing the wash water for the cleansing of the filter.

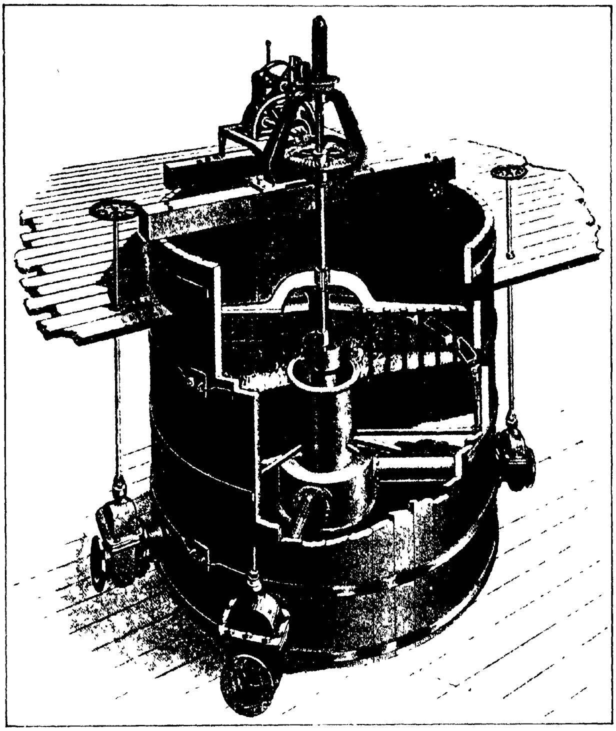


Fig. 65
Warren Gravity Filter

The New York House Filter has as its adjunct to the reversed flow of water a revolving rake, easily turned by hand. The filter is connected with the main supply line in the basement or cellar of a residence or other building and the entire operation controlled by one valve. Once a day the handle is turned in the opposite direction, which allows the water to enter the filter in the reverse direction—at the bottom—and after flowing for ten minutes all the dirt taken from the water during the day's run will be washed out into the sewer.

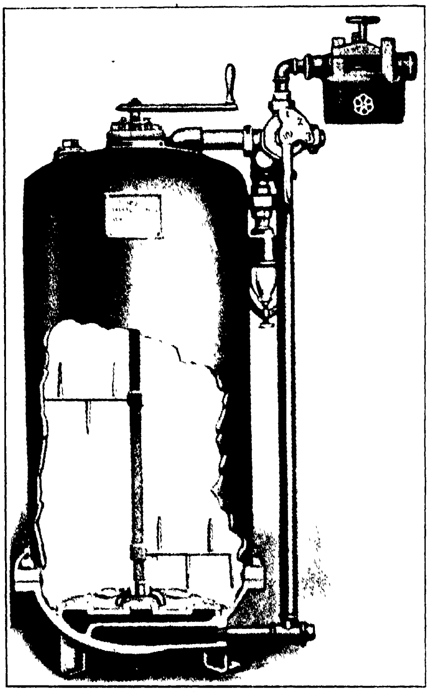


Fig. 66
New York House Filter

In the New York Sectional Wash Filter, Figure 67, the second wash principle is employed, the strainer being divided into sections into each of which in turn the reverse current is concentrated. The entire force of the reverse current is directed against one-third section of the bed only, for about five minutes, then shut off and the central third is scoured in the same manner, and lastly the remaining third is washed. No power or machinery for stirring is here used.

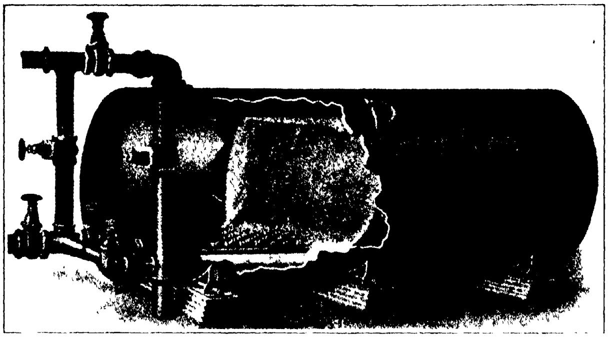


Fig. 67
New York Sectional Wash Filter

The Continental Filter employs compressed air which passes upwards through the bed ahead of the reversed flow of water and disintegrates the bed by a scrubbing effect. Filtration may be double through sand and then through bone charcoal or simply through a large area at a slower rate or through two cylinders each having a 3-foot deep bed of sand.

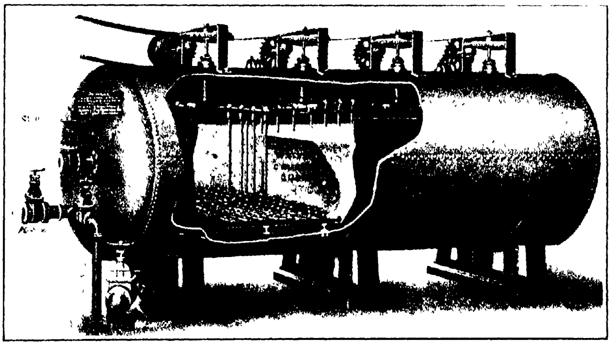


Fig. 68
Jewell Filter

The Jewell Filter of all sizes is equipped with revolving rakes, Figure 68, in the smaller sizes revolved by hand and in the larger by power.

None of the various adjuncts or rakes, etc., are necessary to the filtering process but they assist in washing and in maintaining the efficiency of the machines. The valves are hydraulically controlled and operated.

Each filter is equipped with an indicating loss of head gauge mounted upon its operating table. The effluent from each filter is controlled by means of a Simplex rate of flow controller. These controllers are provided with hydraulic cylinders by means of which the effluent valves may be operated from the operating tables independently of the automatic controlling elements of the effluent controllers proper.

Within the clear well, a float is provided, which actuates a pilot valve which in turn supplies water to the hydraulic cylinders of all effluent controllers in operation, and in the event of the water level in the clear well rising to a predetermined point, all the filters will thus be made to automatically shut off, and when the water recedes in the clear well, the controllers will automatically open and the filters continue in service.

Wash water for the filters is supplied by means of a steam turbine operated centrifugal pump, located in the high service pump room, which supplies wash water during washing of the filters at a rate of about 14 gallons per square foot of filtering area per minute. An auxiliary connection has also been installed from the high service pump discharge line to the wash water main by means of which filters can be washed directly from city pressure in event of the wash water pump being out of service. On this connection a pressure reducing valve has been installed in order to reduce the pressure from the high service line to a point suitable for wash water applications to the filters.

Power Plant Specialty Company.—The softening of boiler feed water is a necessity in numerous plants especially in the Middle West and the Vater Water Softening, System, manufactured by the Power Specialty Company, is one of the filters used for this class of work in the lime and soda ash process.

Lime and soda ash only are used for this method of softening, and treatment is carried on at about 200° F. The water is filtered through a vertical sand filter as illustrated in Figure 69, cleaning of the sand being accomplished by reverse current. The construction and operation of the filter is so similar to the ones already described that it need not be taken up. The company emphasizes the softening of the water rather than the filter construction and therefore the process will be considered at greater length under Chapter XIII, on coagulants and filter aids.

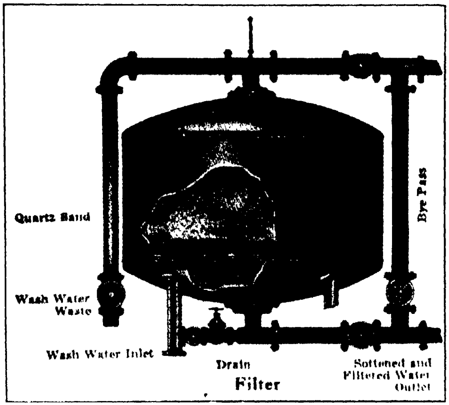


Fig 69
Lime and Soda Water Softener

Pittsburgh Filter Manufacturing Company.—Like other water filter manufacturers who construct water filters generally, the Pittsburgh Filter and Engineering Company make two classes of filters, pressure filters and gravity filters. The pressure type is of steel construction and in the vertical style and is used in small units where head room or floor space is a serious consideration. This includes hotels, hospitals, libraries, railroad water stations, etc., the capacities ranging from 3,000 to 200,000 gallons per day. For larger demands a horizontal type is constructed which will handle 500,000 gallons a day. The gravity filters are usually constructed of wood or steel, although concrete is sometimes used. This type has the advantage of being less liable to derangement, is open for inspection and requires only gravity for pressure. These filters are used in paper mills and large industrial works and for municipal water in small towns

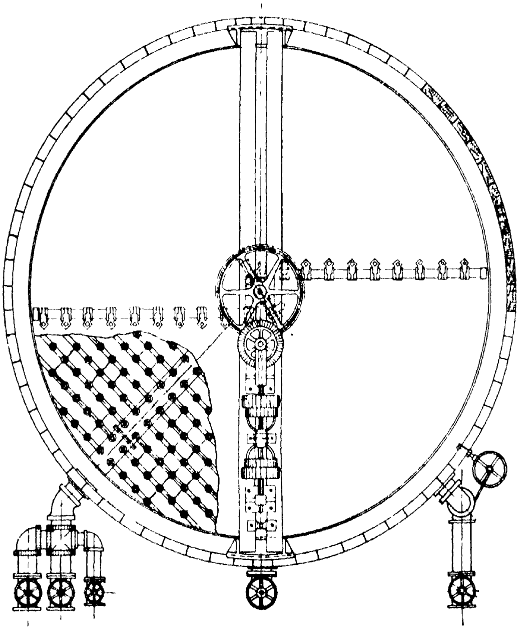


Fig. 70
Pittsburgh Gravity Filter

The Pittsburgh Gravity Filters are round where constructed of wood, Figure 70, or steel and rectangular when made of concrete, as is true of most gravity apparatus. The filters are equipped with gate valves for controlling the inlet, outlet, and wash-water supply. The inlet is supplied with a controlling float valve to regulate the supply to the filter and the outlet is controlled by an automatic rate controller. Filters are made with standard rake agitators operated by gears and belts or with air agitation system. The manifold illustrated in Figure 71 is constructed separately

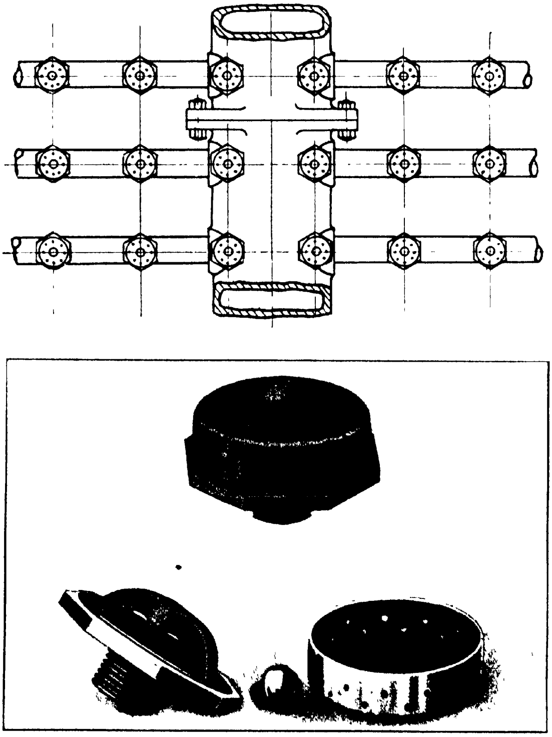

STRAINER AND MANIFOLD

Fig. 71
Strainer

for the distribution of air and water. The air manifolds are heavy brass tubes perforated at intervals and arranged to give a uniform distribution of air pressure to all parts of the sand bed. The water manifold consists of sections of cast-iron securely fastened together and designed with large areas. From the central manifolds are lateral branches spaced on proper centers, covering the entire bottom of the filter compartment; into these laterals are fastened the bronze screens spaced on proper centers each way.

The vertical type pressure filters are made of either boiler plate steel or cast iron The former may be had with or without agitators but the latter can not be so equipped. Instead, two filters are often used, the first having a bed of sand and the second a bed of charcoal, where coagulation is not desired and the water does not carry a large amount of clay in suspension. The horizontal pressure filters are sometimes provided with a settling compartment for muddy water as shown in Figure 72

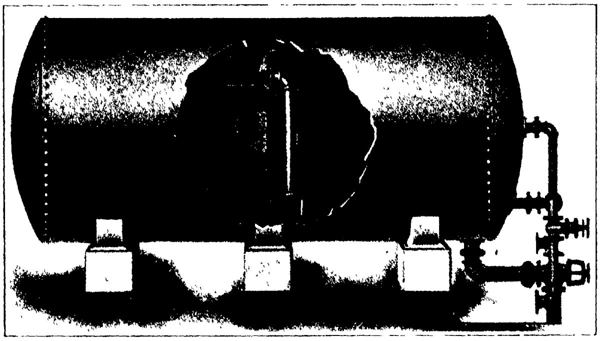


Fig 72
Horizontal Pressure Filter

The use of charcoal enables purification to be obtained as well as clarification and often eliminates the use of coagulents.

Wm. H. Brey.—The Keystone Pressure Filter, Figure 73, made by Wm. H. Brey is a vertical machine constructed of steel to withstand heavy pressures. It is built in nine sizes ranging from 2 to 10 feet in diameter and from 12,000 to 300,000 gallons filtering capacity per day of 24 hours. The filters are very much like the other vertical styles heretofore described, having a mechanical agitator, strainer, sand bed, etc., but have the special feature of a hydraulic agitator in addition to the mechanical one. The filter

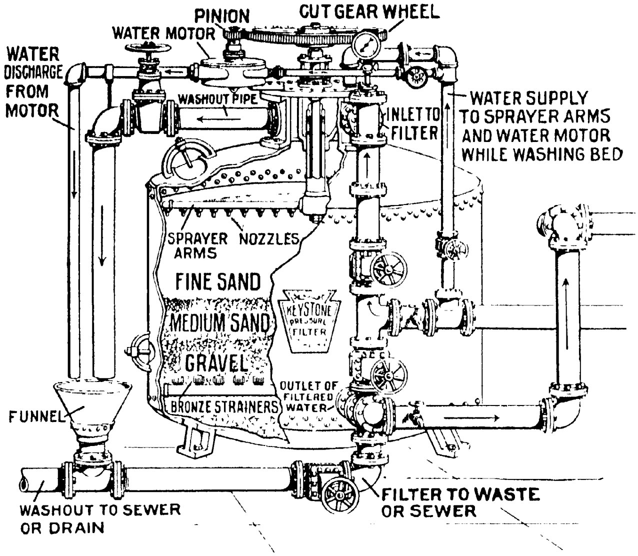


Fig 73
Keystone Pressure Filter

using the hydraulic agitator has four spray arms under the filter just above the top of the sand bed These arms contain small bronze nozzles through which water is forced and they are so arranged that each square inch of the top bed is broken up, scoured and washed. The stream of water is thrown with great force into the sand and at the same time the arms revolve slowly. The top of the filter is fitted with a water motor or a tight and loose pulley, which operates the gear wheels and turns the spray arms.

The company specializes in water softening and purifying and therefore recommends its apparatus particularly for bottling works, ice plants and for boiler feed water.

The claim of special washing efficiency by reason of the spray arms is often disputed as the force of the jet is soon spent and only the sand in the immediate vicinity is benefited.

Roberts Filter Manufacturing Company.—The Roberts Filter Company makes the Roberts Gravity Filter and the Roberts Pressure Filter; which machines are the same as other water filters in construction and operation The gravity filters are made in sizes from 6 to 17 feet in diameter, and the pressure filters with capacities of from one gallon per hour to over a million gallons per hour In the gravity filters all functions are controlled by hand wheels or by operating tables, the former being filters constructed of wood or steel and the latter being concrete apparatus. The vertical pressure filters, Figure 74, are built of iron or steel and equipped with a single control valve, coagulant tank, sight glass and baffle plate. The horizontal pressure tanks are constructed to sustain an internal hydrostatic test pressure of 100 pounds per square inch. The heads are in one piece and dished to a radius of 8 feet in the horizontal style but made convex in the vertical type. The filters employ sand, quartz, marble, or refined bone charcoal as a filter medium, one or more filters being connected together for capacity or for reverse flow and cleaning.

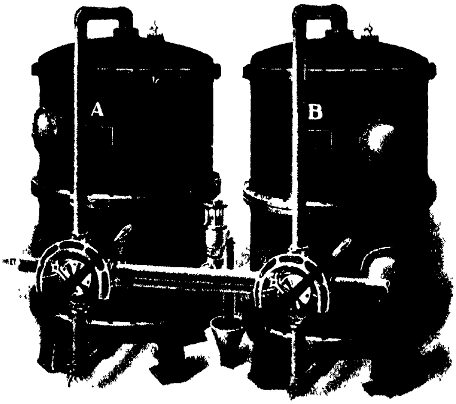


Fig 74
Vertical Pressure Filter

These machines cover a wide range of waters and by reason of their various filtering beds can be especially adapted to the problem at hand.

The Permutit Company.—Practically all types of water filters are manufactured by the Permutit Company but their specialty is water softening by means of zeolites. The chemical reactions which take place by this treatment will be discussed in Chapter XIII.

The Permutit Zeolite Softener consists essentially of a bed of the mineral suitably supported in an open or closed container. The water to be softened, percolates through this bed of mineral which removes the hardness automatically as the water flows through. When the specified capacity of the softener has been reached as indicated by a meter, it is restored to its original condition (regenerated) by passing through it a solution of common salt which is thereafter run to the sewer.

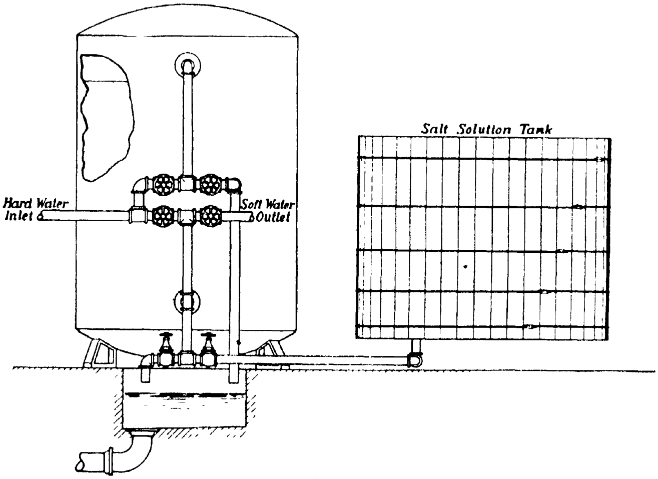


Fig. 75
Permutit System

The accompanying sketch, Figure 75, illustrates the usual form of the steel pressure type of Permutit Zeolite Softener. The regeneration with salt solution is accomplished by opening two valves which permit the brine to siphon through the softener automatically. When the salt solution tank is empty, the brine is rinsed from the softener which is again ready to soften its specified capacity of water.

Where 24-hour operation is required, one softner treats the water while the other is regenerated and they are consequently switched at proper intervals to provide continuity of operation. A tank is provided to make the brine, and its flow to and from the softeners is automatically accomplished. The zeolite is then rinsed free of brine and the softener is again thrown into service by opening the necessary valves.

The Refinite Company.—Refinite is a natural zeolite found in South Dakota and used by The Refinite Company for their water

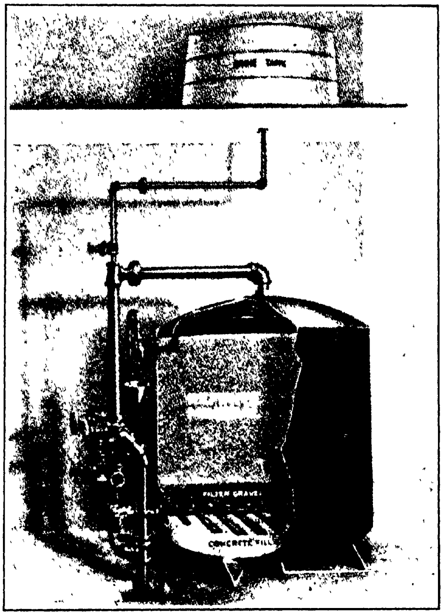


Fig. 76.
Refinite Water Softener

softeners, Figure 76. Its action is of course practically the same as that of Permutit as is the operation of the filter.

The Refinite Water Softening System consists of a simple steel container, provided with proper water inlet and outlet openings together with the necessary piping and valves for controlling the flow of water to be passed through it.

These containers vary in size, from 12 inches in diameter to 96 inches in diameter, to suit any requirements from those of the home to those of the largest industry.

In this container is placed a bed of Refinite mineral, usually about 36 inches in depth. The bed of mineral is supported by a layer of gravel resting upon the soft water collector system, Figure 77.

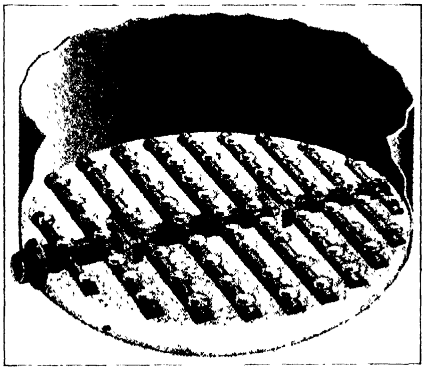


Fig 77

Bottom Section of Container showing Soft Water Collector System

The collector system of the refinite softener really serves two important purposes. During the softening operation it uniformly collects the soft water from all portions of the Refinite mineral bed. During the backwash, or cleansing operation, when the water is passed upward through the softener, the collector system also insures an even distribution of the water to all parts of the mineral bed.

The backwashing operation requires only a few minutes of the operator's time, and is performed to loosen up the particles of Refinite in the mineral bed, just prior to letting in the regenerating brine solution.

In this way it is assured that the brine will thoroughly regenerate the Refinite mineral. The backwashing process also serves to remove any foreign particles which may have accumulated in the mineral bed through its filtering action.

During the softening operation the water passes through a valve into the top of the steel container. By means of a baffle, Figure 76, it is evenly distributed, so that it filters uniformly through the Refinite mineral bed, and into the soft water collector system at the bottom.

From the collector system at the bottom it passes out through a valve and through a meter which measures the number of gallons softened. During the softening operation all other valves are kept closed.

In the backwashing operation the water flows through the softener in exactly the opposite direction, entering at the bottom, passing upward through the Refinite mineral bed and out through the top opening of the container to the drain.

Like the Permutit Company the filter possesses the great advantage of being automatically regenerated by the simple addition of salt brine and is very positive in its action These zeolite water softeners are much superior to the old type of softener and are of great service where water of 1 degree or more hardness is encountered. They have also been used as clarifiers on soft waters with good results.

The life of the water filter is very long whether it be of the gravity or pressure type and the cost of maintenance is low. The filtering bed will as a rule last for six or seven years without renewal and the time for cleaning only consumes about 10 minutes once a day, except of course in the case of the zeolite filters where 10 hours are necessary for regenerating the filter bed.

In the past gravity filters were given an almost entire monoply on municipal and large industrial installations and a very careful record has been kept of their performances under varying conditions. The fact that they were open to inspection, presented a neat appearance, were equipped with perfected filtering beds and strainers, automatic controllers, and there were reliable records which could be depended upon for contemplated installations, made it very difficult for pressure filters to gain an entree into this field. At the present time however, as a result of the successful operation of pressure water filters in several municipalities, some very accurate records are available and the pressure water filters are growing more and more in favor for all kinds of water filtration. There is no reason why perfected strainers and filter beds cannot be used in all cases and the adaptation of automatic controllers is a simple matter. In addition, pressure filters are much less expensive, quicker to install, occupy less space, are entirely above ground, often eliminate clear wells and settling basins, are quickly washed and give high rates of flow. The commonly accepted rate of 2 feet per square foot of filtering surface can be greatly increased. The resistance or back pressure varies from 1½ to 2 pounds immediately after cleaning and gradually increases as the impurities accumulate by interception on the sand bed, to from 10 to 15 pounds or more, depending upon the length of runs between washings, turbidity of water and rate of filtration. After each washing the resistance falls back to 1½ to 2 pounds. The negative head encountered in the gravity filters is avoided as the pressures are all positive This negative head in filtering clear-colored waters often causes trouble as the alum forms fragile, feathery flocs which pass to the underside of the sediment layer by reason of the suction effect This suction effect acting in conjunction with the scouring action of the water passing through the filter detaches particles of hydrate and draws them deep into the bed until they find a lodging place where the combined effect of the two forces is less The action progresses downward until finally the particles emerge with the effluent.

In the future mechanical water filtration with the use of coagulents will probably continue to gain in favor, especially as gravity filters seem to have reached their highest development in their present form while there is still much room for improvement in the pressure type

APPENDIX

USEFUL INFORMATION

A gallon of water (U. S. Standard) weighs 8⅓ pounds and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds and contains 1728 cubic inches, or 7½ gallons.

It takes 30 pounds, or 3.6 gallons, for each horsepower per hour; *e g*, 100 horsepower boiler will require 360 gallons per hour, or 3,600 per day of ten hours.

To find the number of gallons of water a pump will deliver per minute, square the diameter of the water cylinder and multiply by four.

To find the diameter of a pump cylinder to move certain quantities of water, divide the number of gallons needed per minute by four and extract the square root.

To find the area of a piston, square the diameter and multiply by .7854.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 434

To find the height of a column of water in feet, the pressure being known, multiply the pressure shown on gauge by 2.31.

The fewer bends in a suction pipe, the more effective will be the pump's action.

To find the capacity of a cylinder in gallons, multiply the area in inches by the length of stroke in inches. This will give the number of cubic inches. Divide this by 231 for the number of gallons.

The delivery pipes of most modern steam pumps are about one-half the diameter of their pump cylinders; this makes the velocity of the flow of water through them about four times greater

To find the horsepower necessary to elevate the water to a given height, multiply the total weight of the column of water in pounds by the velocity per minute in feet, and divide the product by 33,000 (an allowance of 25 per cent. should be added for friction, etc.).

To ascertain the capacity of a tank, multiply the square of the diameter by the number 5.873, and the result will be the number of gallons to one foot in depth. Multiply this by the height of tank in feet.

Example:—Tank, 10 feet in diameter: 10 x 10 x 5.873 equals 587.300 gallons to each foot in height.

FLOW OF WATER IN NEW PIPES. CAPACITY IN GALLONS PER MINUTE
FRICTION HEAD IN FEET PER 100 FEET LENGTH OF PIPE
VELOCITY IN FEET PER SECOND

Velocity	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Velocity
	Diameter of Pipe												
	1″		2″		3″		4″ C = 0.115		5″ C = 0.0894		6″ C = 0.0723		
3	7	5.4	29	2.4	66	1.4	117	1.0	154	0.8	264	0.7	3
4	10	8.9	39	4.0	88	2.5	157	1.8	245	1.4	352	1.2	4
5	12	13.4	50	6.1	110	3.8	196	2.9	306	2.2	440	1.8	5
6	15	18.3	59	8.5	132	5.4	235	4.1	367	3.2	528	2.6	6
7	17	25.0	69	11.4	154	7.2	274	5.6	428	4.4	617	3.5	7
8	20	31.9	78	14.6	176	9.1	314	7.3	490	5.7	706	4.6	8
8½	21	35.6	83	16.3	187	10.4	334	8.2	521	6.4	749	5.2	8½
9	22	39.6	88	18.2	198	11.3	352	9.3	551	7.2	794	5.9	9
9½	23	43.5	93	19.9	209	12.5	372	10.3	581	8.0	837	6.5	9½
10	24	48.0	98	21.6	220	13.7	391	11.5	612	8.9	882	7.2	10
10½	26	52.6	103	23.8	231	15.0	411	12.0	642	9.4	925	7.6	10½
11	27	57.8	108	26.0	242	16.4	431	13.9	673	10.8	970	8.7	11
11½	28	62.5	113	28.0	253	17.8	450	15.1	703	11.7	1013	9.5	11½
12	29	68.0	118	30.6	264	19.4	471	16.5	735	12.9	1058	10.4	12
13	32	79.3	127	35.6	286	22.4	510	19.4	796	15.1	1145	12.2	13
14	34	91.2	137	41.0	308	25.8	549	22.6	857	17.5	1233	14.2	14
15	37	101.0	147	46.6	330	29.4	587	25.9	918	20.2	1321	16.3	15
	8″ C = 0.0523		10″ C = 0.0409		12″ C = 0.0335		14″ C = 0.0284		16″ C = 0.0246		18″ C = 0.0218		
3	470	0.5	734	0.4	1058	0.3	1438	0.3	1875	0.2	2380	0.2	3
4	627	0.8	979	0.7	1410	0.5	1920	0.5	2500	0.4	3173	0.3	4
5	783	1.3	1224	1.0	1763	0.8	2400	0.7	3125	0.6	3966	0.5	5
6	940	1.9	1469	1.5	2115	1.2	2880	1.0	3750	0.9	4758	0.8	6
7	1007	2.6	1714	2.0	2408	1.6	3360	1.4	4375	1.2	5552	1.1	7
8	1253	3.3	1958	2.6	2820	2.1	3840	1.8	5000	1.6	6345	1.4	8
8½	1332	3.8	2081	2.9	2996	2.4	4075	2.0	5300	1.8	6742	1.6	8½
9	1410	4.2	2203	3.3	3173	2.7	4320	2.3	5625	2.0	7138	1.8	9
9½	1488	4.7	2326	3.7	3349	3.0	4550	2.6	5925	2.2	7535	2.0	9½
10	1567	5.2	2448	4.1	3525	3.4	4795	2.8	6250	2.5	7931	2.2	10
10½	1646	5.5	2571	4.3	3701	3.5	5030	3.0	6563	2.6	8329	2.3	10½
11	1724	6.3	2693	5.0	3878	4.1	5265	3.4	6875	3.0	8725	2.6	11
11½	1802	6.8	2815	5.4	4054	4.4	5500	3.7	7200	3.2	9122	2.9	11½
12	1880	7.5	2938	5.9	4230	4.8	5750	4.1	7500	3.5	9518	3.1	12
13	2037	8.8	3182	6.9	4583	5.7	6225	4.8	8125	4.2	10310	3.7	13
14	2194	10.2	3427	8.0	4935	6.6	6705	5.6	8750	4.8	11104	4.3	
15	2350	11.7	3672	9.2	5288	7.6	7190	6.4	9375	5.5	11897	4.9	15
	20″ C = 0.0195		24″ C = 0.0161		30″ C = 0.0128		36″ C = 0.0106		42″ C = 0.0091		48″ C = 0.0079		
3	2937	0.2	4230	0.1	6609	0.1	9518	0.1	12942	0.1	16930	0.1	3
4	3916	0.3	5640	0.3	8812	0.2	12690	0.2	17256	0.1	22580	0.1	4
5	4896	0.5	7050	0.4	11015	0.3	15863	0.3	21570	0.2	28225	0.2	5
6	5875	0.7	8460	0.6	13218	0.5	19036	0.4	25884	0.3	33870	0.3	6
7	6854	1.0	9870	0.8	15421	0.6	22208	0.5	30198	0.4	39515	0.4	7
8	7834	1.2	11280	1.0	17624	0.8	25381	0.7	34512	0.6	45160	0.5	8
8½	8323	1.4	11985	1.2	18725	0.9	26967	0.8	36669	0.7	47986	0.6	8½
9	8812	1.6	12690	1.3	19827	1.0	28554	0.9	38826	0.7	50805	0.6	9
9½	9302	1.8	13395	1.4	20928	1.1	30104	1.0	40983	0.8	53631	0.7	9½
10	9792	2.0	14100	1.6	22030	1.3	31726	1.1	43142	0.9	56450	0.8	10
10½	10281	2.0	14805	1.7	23131	1.3	33313	1.1	45299	1.0	59276	0.8	10½
11	10771	2.4	15510	1.9	24233	1.5	34899	1.3	47454	1.1	62095	1.0	11
11½	11258	2.6	16215	2.1	25338	1.7	36485	1.4	49611	1.2	64921	1.0	11½
12	11750	2.8	16920	2.3	26436	1.8	38072	1.5	51768	1.3	67740	1.1	12
18	12729	3.3	18330	2.7	28639	2.2	41244	1.8	56082	1.5	73380	1.3	13
14	13708	3.8	19740	3.2	30842	2.5	44417	2.1	60396	1.8	79030	1.5	14
15	14688	4.4	21150	3.8	33045	2.9	47590	2.4	64710	2.0	84675	1.8	15

H (Friction head) = CV^2

C = Coeff. above listed

V = Velocity ft. per second

In short turn 90° bends the Friction head $= \frac{V^2}{g} = \frac{V^2}{32.2}$

$g = 32.2$

AVERAGE WEIGHTS OF MATERIALS IN POUNDS

	Weight per cubic foot		Weight per cubic foot		Weight per cubic foot
Aluminum	162	Gravel, clean	100	Sand, dry	90
Anthracite, solid	93	Gravel, sand and clay, dry	100	Sand, wet	115
Anthracite, broken, loose	54	Gravel, sand and clay, wet	115	Silver	655
Brass (copper and zinc), cast	504	Ice	58	Slate	175
Brass, rolled	524	Iron, cast	450	Snow, fresh	8
Brick, pressed	150	Iron, wrought, average	480	Steel	490
Brick, common	125	Lead	711	Stone, broken	95
Brick, soft	100	Lime, quick, ground, loose, or in small lumps	53	Tar	62
Brickwork, pressed, thin joints	140	Lime, quick, ground, loose, thoroughly shaken	75	Timber:	
Brickwork, common, 3/8-inch joints	120	Lime, per barrel	230	Cedar, dry	23
Brickwork, soft, 3/8-inch joints	100	Masonry, granite ashlar	165	Cypress	29
Bronze	529	Masonry, limestone marble ashlar	160	Fir, yellow and red	30
Cement, Portland, per barrel, net	376	Masonry, sandstone ashlar	140	Hemlock, dry	25
Coal, bituminous, solid	85	Masonry, granite, mortar rubble	155	Hickory, dry	53
Coal, bituminous, broken, loose	52	Masonry, limestone, mortar rubble	150	Mahogany, Spanish, dry	53
Coke, loose, of good coal	26	Masonry, sandstone, mortar rubble	130	Mahogany, Honduras, dry	35
Concrete, cinder	110	Masonry, granite, dry rubble	130	Maple, dry	49
Concrete, broken stone or gravel	145	Masonry, limestone, dry rubble	125	Oak, white, dry	50
Concrete, stone or gravel, reinforced	150	Masonry, sandstone, dry rubble	110	Pine, white, dry	25
Copper, cast	542	Mortar, lime, hard	105	Pine, yellow, short-leaf, dry	35
Copper, rolled	548	Mortar, natural cement, hard	120	Pine, yellow, long-leaf, dry	40
Earth, common loam, dry, loose	76	Mortar, Portland cement, hard	135	Pine, red, Norway, dry	31
Earth, common loam, dry, rammed	100	Mud, dry, close	80-100	Redwood, California, dry	24
Earth, common loam, as a soft flowing mud	110	Mud, wet	110	Spruce, dry	25
Glass, common window	157	Quartz, common, pure	165	Tin, cast	459
Gold, cast, pure, or 24 carat	1204	Rock, loose	100	Water, salt	64
Granite	170			Zinc or Spelter	437½

TABLE SHOWING THE QUANTITY OF WATER PASSING OVER WEIRS IN CUBIC FEET PER MINUTE

Depth of water on weir in inches	Cubic feet per minute passed for each foot of length of weir	Depth of water on weir in inches	Cubic feet per minute passed for each foot of length of weir	Depth of water on weir in inches	Cubic feet per minute passed for each foot of length of weir
1	4.85	7	89.82	13	227.30
1¼	6.68	7¼	94.67	13¼	233.92
1½	8.90	7½	99.50	13½	240.54
1¾	11.23	7¾	104.63	13¾	247.22
2	13.75	8	109.74	14	254.03
2¼	16.36	8¼	114.91	14¼	260.83
2½	19.17	8½	120.18	14½	267.77
2¾	22.11	8¾	125.52	14¾	274.70
3	25.20	9	130.93	15	281.72
3¼	28 43	9½	136.43	15¼	288.82
3½	31.75	9¼	141.99	15½	295.93
3¾	35.22	9¾	147.64	15¾	303.10
4	38.80	10	153.35	16	310.36
4¼	42.49	10¼	159.14	16¼	317.69
4½	46.29	10½	164.99	16½	325.03
4¾	50.20	10¾	169.92	16¾	332.42
5	54 22	11	176.92	17	339.91
5¼	58.33	11¼	182.99	17½	355.02
5½	62.55	11½	189.13	18	370.34
5¾	66.86	11¾	195.32	18½	385.87
6	71.27	12	201.59	19	401.63
6¼	75.77	12¼	207.94	19½	417.48
6½	80.36	12½	214.32	20	433.58
6¾	85 04	12¾	220.76		

REQUIRED AREA OF FILTERS FOR VARIOUS RATES OF FILTRATION

Gals per sq. ft per min	Gals. per sq. ft. per hr.	Gals per sq. ft per day (24 Hrs.)	Gals. per acre per day (24 Hrs.)	Filtering area in sq. ft. per mil. gals. per 24 hours
0.797	47.8	1147	50,000,000	871
0.875	52.5	1260	55,000,000	792
0.956	57.4	1377	60,000,000	726
1.035	62.1	1490	65,000,000	670
1.115	67.0	1607	70,000,000	622
1.195	71.8	1722	75,000,000	581
1.275	76.5	1837	80,000,000	545
1.355	81.3	1950	85,000,000	513
1 435	86.1	2066	90,000,000	484
1.517	91.0	2181	95,000.000	459
1.595	95.7	2296	100,000.000	437
1.675	100.5	2411	105,000,000	415
1.752	105.1	2524	110,000,000	396
1.835	110.0	2640	115,000,000	379
1.913	114.8	2755	120,000,000	363
1.992	119.5	2870	125,000,000	348
2.066	124.0	2984	130,000,000	335
2.145	128.7	3090	135,000,000	322

CAPACITIES IN GALLONS PER FOOT OF DEPTH OF CYLINDRICAL VESSELS, TANKS, ETC.

Diam Ft.	In.	Gallons per ft. Depth	Diam Ft.	In.	Gallons per ft Depth	Diam. Ft.	In.	Gallons per ft. Depth
1		5.8	9	6	530.2	20	6	2469.1
1	2	8.0	9	9	558.5	20	9	2526.6
1	4	10.4	10		587.5	21		2591.0
1	6	13.2	10	3	617.2	21	3	2653.0
1	8	16.3	10	6	647.7	21	6	2715.8
1	10	19.7	10	9	678.9	21	9	2779.3
2		23.5	11		710.9	22		2843.6
2	2	27.5	11	3	743.5	22	3	2908.6
2	4	31.9	11	6	776.9	22	6	2974.3
2	6	36.7	11	9	811.4	22	9	3040.8
2	8	41.7	12		846.0	23		3108.0
2	10	47.1	12	3	881.6	23	3	3175.9
3		52.8	12	6	918.0	23	6	3244.6
3	2	58.9	12	9	955.0	23	9	3314.0
3	4	65.2	13		992.9	24		3384.1
3	6	71.9	13	3	1031.5	24	3	3455.0
3	8	78.9	13	6	1070.8	24	6	3526.6
3	10	86.3	13	9	1110.8	24	9	3598.9
4		94.0	14		1151.5	25		3672.0
4	2	102.0	14	3	1193.0	25	3	3745.8
4	4	110.3	14	6	1235.3	25	6	3820.3
4	6	118.9	14	9	1278.2	25	9	3895.6
4	8	127.9	15		1321.9	26		3971.6
4	10	137.2	15	3	1366.4	26	3	4048.4
5		146.8	15	6	1411.5	26	6	4125.9
5	2	156.8	15	9	1457.4	26	9	4204.1
5	4	167.1	16		1504.1	27		4283.1
5	6	177.7	16	3	1551.4	27	3	4362.7
5	8	188.6	16	6	1599.5	27	6	4443.1
5	10	199.9	16	9	1648.4	27	9	4524.3
6		211.5	17		1697.9	28		4606.2
6	3	229.5	17	3	1748.2	28	3	4688.8
6	6	248.2	17	6	1799.3	28	6	4772.1
6	9	267.6	17	9	1851.1	28	9	4856.2
7		287.8	18		1903.6	29		4941.0
7	3	308.8	18	3	1956.8	29	3	5026.6
7	6	330.4	18	6	2010.8	29	6	5112.9
7	9	352.8	18	9	2065.5	29	9	5199.9
8		376.0	19		2120.9	30		5287.7
8	3	399.8	19	3	2177.1	30	3	5376.2
8	6	424.4	19	6	2234.0	30	6	5465.4
8	9	449.8	19	9	2291.7	30	9	5555.4
9		475.8	20		2350.1	31	0	5646.1
9	3	502.7	20	3	2409.2	32	0	6016.2

USEFUL FORMULAS RELATIVE TO CENTRIFUGAL FORCE

Nomenclature

A = Sectional area in square inches.
d = Diameter in inches.
F = Centrifugal force in pounds.
g = Acceleration due to gravity = 32.16 ft. per second.
H = Centrifugal head.
N = Number of revolutions per minute.
R = Radius in feet.
S = Tensile strain in pounds per square inch.
V = Velocity in feet per second. $= \frac{1}{30} N \pi R$.
V_1 = Velocity of outer surface of revolving liquid.
V_2 = Velocity of inner surface of revolving liquid.
W = Weight in pounds.
$\pi = 3.1416$.
V_3 = Velocity in feet per minute.

FORMULA FOR CENTRIFUGAL FORCE

$$F = \frac{WV^2}{gR} = \frac{WV^2}{32.16R} = \frac{W4\pi^2RN^2}{3600g} = \frac{WRN^2}{2933} = .0003410WRN^2 = .00001417WdN^2$$

FORMULA FOR CENTRIFUGAL HEAD

(For head of revolving body of liquid)

$H = \frac{V1^2}{2g} - \frac{V2^2}{2g}$ will give the centrifugal head in feet.

FORMULA FOR TENSILE STRAIN IN REVOLVING BANDS

(Due to their own weight)

$$S = \frac{.00001417WdN^2}{6.2832A} = \frac{.000002255WdN^2}{A} = V3^2 \text{ times constant}$$

Constant for copper = .0000332
Constant for steel = .0000294
Constant for wrought iron = .000288
Constant for cast steel = .0000270
Constant for wood = .00000225

PROPERTIES OF SATURATED STEAM.

Total pressure per square inch measured from a vacuum	Pressure above the atmosphere or by steam gauges	Sensible temperature in Fahrenheit Degrees	Total heat in degrees from zero of Fahrenheit	Weight of one cubic foot of steam	Relative volume of the steam compared with the water from which it was raised
Lbs	Lbs	Degrees	Degrees	Lbs	
40	25.3	267.3	1194.9	.0974	640
45	30.3	274.4	1197.1	1089	572
50	35.3	281.0	1199.1	.1202	518
55	40.3	287.1	1201.0	.1314	474
60	45.3	292.7	1202 7	.1425	437
65	50.3	298.0	1204.3	.1538	405
70	55.3	302 9	1205.8	.1648	378
75	60.3	307.5	1207.2	.1759	353
80	65.3	312 0	1208 5	.1869	333
85	70.3	316.2	1209.9	1980	314
90	75.3	321.0	1211.1	.2089	298
95	80.3	324 8	1212.3	.2198	283
100	85 3	327 9	1213.4	.2307	270
105	90.3	331.3	1214.4	.2414	257
110	95.3	334.6	1215.5	.2521	247
115	100 3	338 0	1216.5	.2628	237
120	105.3	341.1	1217.4	.2759	227
125	110.3	344.2	1218.4	2867	219
130	115.3	347.2	1219.3	.2977	211
135	120.3	350.1	1220.2	.3080	203
140	125.3	352.9	1221.0	.3184	197
145	130 3	355.6	1221.9	.3294	190
150	135.3	358.3	1222.7	.3397	184
155	140.3	361.0	1223.5	.3500	179
160	145.3	363 4	1224.2	.3607	174
165	150.3	366.0	1224.9	.3714	169
170	155.3	368.2	1225.7	.3821	164
175	160.3	370.8	1226.4	.3928	159
180	165.3	372 9	1227.1	.4035	155
185	170.3	375.3	1227.8	.4142	151
190	175.3	377.5	1228.5	4250	148
195	180.3	379.7	1229.2	.4357	144
200	185.3	381 7	1229.8	.4464	141

The following table gives the equivalents of million gallons in cubic feet; also the flows per minute and second in cubic feet and gallons when the flow is distributed evenly over 24 hours.

Per 24 hours		Flow equivalents			
Million gallons	Cubic feet equivalent	Cubic feet per minute	Cubic feet per second	U S gallons per minute	U. S. gallons per second
1	133,680.55	92.88	1 5481	694.44	11.57
2	267,361 11	185.77	3.09	1,388.88	23.14
3	401,041.67	278 66	4.64	2,083.33	34.72
4	534,722.22	371.55	6.19	2,777.77	46.29
5	668,402.78	464.44	7.74	3,472.22	57.87
6	802,083.34	557 33	9.28	4,166.66	69 44
7	935,763.89	650.22	10.83	4,861.11	81.01
8	1,069,444.45	743.11	12 38	5,555.55	92.59
9	1,203,125.01	836.00	13.93	6,249 99	104.16
10	1,336,805.56	928.89	15 48	6,944.44	115.74
11	1,470,486.12	1,021 78	17.02	7,638.88	127.31
12	1,604,166 68	1,114.67	18.57	8,333.33	138.88
13	1,737,847 24	1,207.56	20.12	9,027.77	150.46
14	1,871,527.79	1,300.44	21.67	9,722.22	162.03
15	2,005,208.35	1,393.33	23.22	10,416.66	173.61
16	2,138,888 91	1,486 22	24 77	11,111.11	185.18
17	2,272,569.46	1,579 11	26.31	11,805.55	196.75
18	2,406,250.02	1,672.00	27.86	12,499.99	208.33
19	2,539,930.58	1,764.89	29 41	13,194.44	219.90
20	2,673,611.13	1,857.78	30.96	13,888.88	231.48
21	2,807,291.69	1,950.67	32.51	14,583.33	243.05
22	2,940,972.25	2,043.56	34.05	15,277.77	254.62
23	3,074,652.81	2,136.45	35.60	15,972.22	266.20
24	3,208,333.36	2,229.34	37.15	16,666.66	277.77
25	3,342,013.92	2,322.23	38.70	17 361.11	289.35
26	3,475,694 48	2,415.12	40.25	18,055.55	300.92
27	3,609,375.03	2,508 01	41.80	18,749.99	312 49
28	3,743,055.59	2,600.89	43.34	19,444.44	324.07
29	3,876,736.15	2,693.78	44.89	20,138.88	335.64
30	4,010,416.70	2,786.66	46.44	20,833.33	347.22
31	4,144,097.26	2,879.56	47.99	21,527.77	358.79
32	4,277,777.82	2,972.45	49.54	22,222.22	370.37
33	4,411,458.38	3,065.34	51.08	22,916.66	381.94
34	4,545,138.93	3,158.23	52.63	23,611.11	393.51
35	4,678,819.49	3,251.12	54.18	24,305.55	405.09
36	4,812,500.05	3,344.01	55.73	24,999.99	416.66
37	4,946,180.60	3,436.90	57.28	25,694.44	428.24
38	5,079,861.16	3,429.79	58.82	26,388.88	439.81
39	5,213,541.72	3,622.68	60.37	27,083.33	451.38
40	5,347,222.27	3,715.57	61.92	27,777.77	462.96
41	5,480,902.83	3,808.46	63.47	28,472.22	474.53
42	5,614,583.39	3,901.49	65.02	29,166.66	486.11
43	5,748,263.95	3,994.23	66.57	29,861.11	497.68
44	5,881,944.50	4,087.12	68.11	30,555.55	509.25
45	6,015,625.06	4,180.01	69.66	31,249.99	520.83
46	6,149,305.62	4,272.90	71.21	31,944.44	532.40
47	6,282,986.17	4,365.79	72.76	32,638.88	543.98

Per 24 hours		Flow equivalent			
Million gallons	Cubic feet equivalent	Cubic feet per minute	Cubic feet per second	U. S gallons per minute	U. S. gallons per second
48	6,416,666.73	4,458.68	74.31	33,333.33	555.55
49	6,550,347.29	4,551.57	75 85	34,027.77	567.12
50	6,684,027.84	4,644 46	77.40	34,722.22	578.70
51	6,817,708.40	4,737.35	78 95	35,416.66	590.27
52	6,951,388.96	4,830.24	80.50	36,111.11	601.85
53	7,085,069.52	4,923.13	82.05	36,805.55	613 42
54	7,218,750 07	5,016.02	83.60	37,499.99	724.99
55	7,352,430.63	5,108.91	85.14	38,194 44	636.57
56	7,486,111.19	5 201.79	86.69	38,888 88	648.14
57	7,619,791 74	5,294 68	88.24	39,583 33	659 72
58	7,753,472.30	5.387 57	89.79	40,277.77	671.29
59	7,887,152 86	5,480 46	91 34	40,972.22	682 87
60	8,020,833.41	5,573.35	92.88	41,666.66	694.44
61	8,154,513 97	5,666.24	94.43	42,361.11	706.01
62	8,288,194.53	5,759.13	95 98	43,055.55	717.59
63	8,421,875 09	5,852.02	97 53	43,749 99	729 16
64	8,555,555.64	5,944 91	99 08	44,444.44	740.74
65	8,689,236.20	6,037 80	100 63	45,138.88	752.31
66	8,822,916.76	6,130 69	102 17	45,833.33	763 88
67	8,956,597 31	6,223.58	103 72	46,527.77	775.46
68	9,090,277.87	6,316 47	105 27	47,222.22	787.03
69	9,223,958.43	6,409.36	106.82	47,916.66	798.61
70	9,357,638.98	6,502.24	108 37	48,611.11	810.18
71	9,491,319.54	6,595.13	109.91	49,305 55	821.75
72	9,625,000.10	6,688 02	111 46	49,999.99	833.33
73	9,758,680.66	6.780 91	113.01	50,694 44	844.90
74	9,892,361.21	6,873 80	114 56	51,388 88	856.48
75	10,026,041.77	6,966 69	116.11	52,083.33	868.05
76	10,159,722.33	7,059.58	117.65	52,777.77	879.62
77	10,293,402.88	7,152 47	119 20	53,472.22	891.20
78	10,427,083.44	7,245 36	120 75	54,166.66	902.77
79	10,560,764.00	7,338.25	122 30	54,861.11	914.35
80	10,694,444.55	7,431.14	123.85	55,555.55	925.92
81	10,828,125.11	7,524 03	125.40	56,249 99	937.49
82	10,961,805.67	7.616 92	126 94	56,944.44	949.07
83	11,095,486.23	7,709 80	128.49	57,638.88	960.64
84	11,229,166.78	7,802.69	130.04	58,333.33	972 22
85	11,362,847.34	7,895.58	131.59	59,027.77	983.79
86	11,196,527.90	7,988.47	133.14	59,722.22	995.37
87	11,630,208.45	8,081.36	134 68	60,416.66	1,006.94
88	11,763,889.01	8,174.25	136.23	61,111.11	1,018.51
89	11,897,569.57	8.267.14	137.78	61,805.55	1,030.09
90	12,031,250.12	8,360.03	139.33	62,499.99	1,041.66
91	12,164,930.68	8.452.92	140.88	63,194.44	1,053.24
92	12,298,611.24	8,545.81	142.43	63,888.88	1,064.81
93	12,432,291.80	8,636.70	143.97	64,583.33	1,076.38
94	12,565,972.35	8,731.59	145.52	65,277.77	1,087.96
95	12,699,652.91	8,824.48	147.07	65,972.22	1,099.53
96	12,833,333.47	8,917.37	148.62	66,666.66	1,111.11
97	12,967,014.02	9,010.25	150.17	67,361.11	1,122.68
98	13,100,694.58	9,103.14	151 71	68,055.55	1,134.25
99	13,234,375.14	9,196.03	153.26	68,750.00	1,145.83
100	13,368,055.69	9,288.92	154.81	69,444.44	1,157.40

CREATING A VACUUM IN A CLOSED TANK

Quite often it is necessary to calculate the size of vacuum pump to exhaust a vessel of known capacity in a stated time to a certain degree of vacuum, and for this purpose the following table has been calculated It gives the volume which must be exhausted from vessels in order to reduce the pressure from one atmosphere P to the lower P_1. If the time is given in which a desired effect is to be produced, the size of pump can be readily calculated.

Table Giving the Number of Cubic Feet That must be Exhausted from a Closed Vessel Containing 100 to 4,500 Cubic Feet in Order to Reduce the Original Internal Pressure from (14 7 lbs) to .9-.01 Atmosphere Absolute or 3″-29 3-4″ Vacuum

The pressure in the vessel is to be reduced from atmosphere—P to — P_1		If the original pressure in a vessel is atmosphere absolute or P and it is to be reduced to P_1 the following volumes of air must be exhausted									
		Capacity of the vessel in cubic feet									
		100	500	1000	1500	2000	2500	3000	3500	4000	4500
Atmos. Abs.	Vac inch	Cubic feet to be exhausted									
.9	3	10.5	53	105	158	210	263	315	368	424	473
.8	6	22.5	113	225	338	450	563	675	788	900	1013
.7	9	35	175	350	525	700	875	1050	1225	1400	1575
.6	12	51	255	510	765	1020	1275	1530	1785	2040	2295
.5	15	69	345	690	1035	1380	1725	2070	2415	2760	3105
.4	18	91.5	458	915	1374	1830	2290	2745	3203	3660	4118
.3	21	120	600	1200	1800	2400	3000	3600	4200	4800	5400
.25	22½	138	690	1380	2070	2760	3450	4140	4830	5520	6210
.2	24	161	805	1610	2415	3220	4025	4830	5635	6440	7245
.15	25½	190	950	1900	2850	3800	4750	5700	6650	7600	8550
.1	27	230	1150	2300	3450	4600	5750	6900	8050	9200	10350
.09	27¼	241	1205	2410	3615	4820	6025	7230	8435	9640	10845
.08	27½	252	1260	2520	3780	5040	6300	7560	8820	10080	11340
.07	27¾	266	1330	2660	3990	5320	6650	7980	9310	10640	11970
.06	28¼	281	1405	2810	4215	5620	7025	8430	9835	11240	12645
.05	28½	300	1500	3000	4500	6000	7500	9000	10500	12000	13500
.04	28¾	322	1610	3220	4830	6440	8050	9660	11270	12880	14490
.03	29	351	1755	3510	5265	7020	8775	10530	12285	14040	15795
.02	29½	391	1955	3910	5865	7820	9775	11730	13685	15640	17595
.01	29¾	460	2300	4600	6900	9200	11500	13800	16100	18400	20700

EXAMPLE

We have a closed tank of 500 cubic feet capacity at atmospheric pressure, and it is desired to exhaust it down to 21″ of vacuum in five minutes time. What capacity in cubic feet per minute must the air pump have?

SOLUTION

Referring to the table opposite 21″ of vacuum it is seen for a vessel of 500 cubic feet capacity, 600 cubic feet must be exhausted If this amounts must be exhausted in five minutes time, the capacity of the air pump must be one-fifth of 600 or 120 cubic feet per minute

If it is required to reduce the pressure in a vessel from P_2, which is lower than the atmosphere to the still lower pressure P_1, in order to calculate the volume of air to be exhausted, in this case, it is necessary to subtract the volume which must be exhausted in order to reduce the pressure from atmosphere to P_2, from that required to reduce the pressure from atmosphere to P_1.

EXAMPLE

The vacuum in a closed tank of 2,000 cubic feet capacity is 15″, and this is to be reduced to 27″ of vacuum. What volume must be exhausted?

SOLUTION

From the table it is seen 4,600 cubic feet must be exhausted to lower the pressure from atmosphere to 27″ of vacuum. Also it will be seen from the table 1,380 cubic feet must be exhausted to lower the pressure from atmosphere to 15″ of vacuum. The difference between these two values equals 3,220 cubic feet that must be exhausted to lower the pressure from 15″ of vacuum to 27″ of vacuum.

Having calculated the capacity required for the vacuum pump, the displacement of the vacuum pump must next be determined. This is calculated by assuming the volumetric efficiency of the vacuum pump as 60-75 per cent. Then the displacement in cubic feet per minute equals the capacity in cubic feet per minute divided by the volumetric efficiency expressed as a decimal.

HORSEPOWER OF AN ENGINE

a = Area of the piston in square inches.
p = Mean effective pressure of the steam on the piston per square inch.
v = Velocity of piston per minute.

$$\text{Then H. P.} = \frac{a \times p \times v}{33{,}000}$$

The mean pressure in the cylinder when cutting off at
¼ stroke = boiler pressure multiplied by .597
⅓ “ = “ “ “ “ .670
⅜ “ = “ “ “ “ .743
½ “ = “ “ “ “ .847
⅝ “ = “ “ “ “ .919
⅔ “ = “ “ “ “ .937
¾ “ = “ “ “ “ .966
⅞ “ = “ “ “ “ .992

To find the diameter of a cylinder of an engine of a required nominal horsepower.

$$\frac{5500}{v} \text{ multiplied by H. P.}$$

RANGES IN STEAM CONSUMPTION BY PRIME MOVERS

Type engine	Saturated steam lbs per hour	100° Super lbs. per hour	200° Super lbs per hour
Simple—Non-condensing	29 45	20—38	18—35
Simple—Non-condensing automatic	26--40	18—34	16—30
Simple -Non-condensing Corliss..	26—35	18—30	......
Compound—Non-condensing	19—28	15—25	13—22
Compound—Condensing	12—22	10- 20	9—17
Turbines Non-condensing (kw-hr.)	28—60	24—54	21—48
Turbines condensing (kw-hr.)	12—42	10—38	9—34

Different Standards for Wire Gauge in Use in the United States

Dimensions of Sizes in Decimal Parts of an Inch

Number of wire gauge	American or Brown & Sharpe	Birmingham or Stubs wire	Washburn & Moen Mfg Co Worcester Mass	Imperial wire gauge	Stubs steel wire	U S standard for plate	Number of wire gauge
000000	....	....	....	461	....	.46875	000000
00000	....	.....	....	.432	....	4375	00000
0000	.46	.454	.3938	400	... ...	40625	0000
000	.40964	.425	.3625	.372	....	.375	000
00	.3648	.38	.3310	.348	....	34375	00
0	.32486	.34	.3065	.324	....	.3125	0
1	.2893	.3	2830	.300	227	.28125	1
2	.25763	.284	2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	232	.207	.234375	4
5	.18194	.22	2070	.212	204	21875	5
6	.16202	.203	.1920	.192	.201	.203125	6
7	.14428	18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	092	.182	09375	13
14	.064084	.083	.0800	080	.180	078125	14
15	.057068	.072	.0720	.072	.178	.0708125	15
16	.05082	.065	.0625	.064	175	.0625	16
17	045257	.058	.0540	056	.172	.05625	17
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	022	.151	.025	24
25	.0179	.02	.0204	020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	·016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0116	.120	.0109375	31
32	.00795	.009	.0128	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453	.....	....	.0068	.103	.006640625	37
38	.003965	......	....	.0060	.101	.00625	38
39	.003531	.....	....	.0052	.099	....	39
40	.003144	......	... ...	.0048	.097	....	40

The Materials and Fittings Used for Pumping Various Liquids.

Direct Acting Pumps, Power Pumps, Crank and Flywheel Pumps

The following table gives the proper materials and fittings to be used on ordinary pumps for handling different kinds of liquids.

Kind of liquid	Material used	Valves	Piston packing
Acetic acid concentrated	All bronze	Bronze disc	Hydraulic
Acetic acid diluted	All bronze	Bronze disc	Hydraulic
Acid mine water	All bronze	Bronze disc	Hydraulic
Alkaline water	All iron fitted	Iron disc	Hydraulic
Alcohol (crude)	Standard bronze fitted	Bronze disc	Hemp
Ammonia water (aqua am.)	All iron fitted	Iron disc	Hydraulic
Anilin water	All iron fitted	Iron disc	Hydraulic
Benzene	All iron fitted	Iron disc	Hemp
Benzine	Standard bronze fitted	Bronze disc	Hemp
Beer	All bronze fitted	Bronze disc	Hydraulic
Beer-wort	All bronze fitted	Bronze disc	Hydraulic
Beet juice (thin)	All iron fitted	Iron disc	Hydraulic
Bisulphite	Standard bronze fitted	Bronze disc	Hemp
Bitter mineral water	All bronze	Bronze disc	Hydraulic
Brine (calcium)	All iron fitted	Iron disc or rubber	Hydraulic
Brine (sodium)	Standard bronze fitted	Bronze disc or rubber	Hydraulic
Cane juice	Full bronze fitted	Bronze disc	Hydraulic
Carbonate of soda	All iron fitted	Iron disc	Hydraulic
Carbonic acid	Standard bronze fitted	Bronze disc	Iron Ring
Caustic carbonate of soda in solution (hot)	All iron fitted	Iron disc	Hemp
Caustic chloride of magnesium soultion (cold)	All iron fitted	Iron disc	Hemp
Caustic Cyanogen in solution	All iron fitted	Iron disc	Hemp
Caustic manganese in solution	All iron fitted	Iron disc	Hemp
Caustic potash solution	All iron fitted	Iron disc	Hemp
Caustic potash niter in solution	All iron fitted	Iron disc	Hemp
Caustic soda solution	All iron fitted	Iron disc	Hemp
Caustic sodium chloride solution	All iron fitted	Iron disc	Hemp
Caustic zinc chloride	All iron fitted	Iron disc	Hemp
Chlorine	Nickel manganese or alloy		
Chloride of potash solution	All iron fitted	Iron disc	Hemp
Caustic chloride of magnesium solution (hot)	Hard lead		
Coal tar oil	All iron fitted	Iron disc	Iron ring
Creosote oil	All iron fitted	Iron disc	Iron ring
Cresol	All iron fitted	Iron disc	Iron ring
Cyanogen	Standard bronze fitted	Bronze disc	Hemp
Cyanide of potassium	All iron fitted	Iron disc	Hemp
Distillery-wort	All bronze	Bronze disc	Hemp
Ferrous chloride	All iron fitted	Iron disc	Hemp
Gasoline	Standard bronze fitted or standard fitted	Bronze disc	Hemp or iron ring packing
Glue (hot)	Full bronze fitted	Bronze ball	Bronze ring
Glycerine	All bronze	Bronze disc	Bronze ring
Grease (hot)	Standard bronze fitted	Bronze disc	Bronze ring
Green vitriol	All iron fitted	Iron disc	Iron ring
Guncotton brine	All iron fitted	Iron disc	Iron ring
Hot oil (300°) max. temp.	Standard bronze fitted	Bronze disc	Bronze ring
Hot oil (over 300°)	All iron fitted	Iron disc	Iron ring Asbestos in piston rod Stuffing box
Heavy oil	Standard bronze fitted	Bronze disc	Bronze ring
Hydrochloric acid in thin solution	All bronze	Bronze disc	Bronze ring
Hydrochloric acid	All bronze	Bronze disc	Bronze ring
Iron pyritic acid	All bronze	Bronze disc	Bronze ring
Lard (hot)	All iron fitted	Iron ball valves	Iron ring

THE MATERIALS AND FITTINGS USED FOR PUMPING VARIOUS LIQUIDS—CONTINUED

Direct Acting Pumps, Power Pumps, Crank and Flywheel Pumps

The following table gives the proper materials and fittings to be used on ordinary pumps for handling different kinds of liquids.

Kind of liquid	Material used	Valves	Piston packing
Lime water	All iron fitted	Iron disc	Hemp
Linseed oil	Standard bronze fitted	Bronze disc	Hemp
Lye (caustic)	All iron fitted	Iron disc	Iron ring
Lye (containing much salt)	Standard bronze fitted	Bronze disc	Hemp
Lye solution (containing sand)	All iron fitted	Iron disc	Hemp
Mash	All bronze	Bronze ball	Hemp
Milk	All bronze	Bronze disc or clapper	Solid bronze piston
Mineral oil	Standard bronze fitted	Bronze disc	Bronze ring
Molasses	Full bronze fitted	Bronze ball	Bronze ring or hemp
Naphtha	Standard bronze fitted	Bronze disc	Iron or bronze ring
Nitric acid (concentrated)	Lead		
Nitric acid (diluted)	All iron fitted	Iron disc	Hemp
Olive oil	Standard bronze fitted	Bronze disc	Bronze ring
Paraffin (hot)	Standard bronze fitted	Bronze ball	Bronze ring
Petroleum	All iron fitted	Iron ball	Iron ring
Petroleum ether	All iron fitted	Iron disc	Hemp
Pitch (hot)	All iron fitted	Iron ball	Iron ring
Potash solution	All iron fitted	Iron disc	Hemp
Pulp	Standard bronze fitted	Special ball valve pump	
Purifying oil	All iron fitted	Iron disc	Iron ring
Rape oil	Standard bronze fitted	Bronze disc	Bronze ring
Rosin (hot)	All iron fitted	Iron disc	Iron ring
Salt water	Full bronze fitted	Bronze disc or rubber	Hydraulic
Sea water	Full bronze fitted	Bronze disc or rubber	Hydraulic
Sewage	Full bronze fitted	Bronze disc or rubber	Hydraulic
Sebacic acid	All bronze	Bronze disc	Hemp
Syrup	Standard bronze fitted	Bronze disc	Bronze ring
Soap water	All iron fitted	Iron disc	Hemp
Soda	All iron fitted	Iron disc	Hemp
Sodium chloride solution	Standard bronze fitted	Bronze disc	Hemp
Sodium sulphate	All iron fitted	Iron disc	Hemp
Stearic acid (hot)	All bronze	Bronze disc	Hemp
Sugar compound	Standard bronze fitted	Bronze disc	Bronze ring
Sugar solution	Standard bronze fitted	Bronze disc	Bronze ring
Sulphate of lime	Standard bronze fitted	Bronze disc	Bronze ring
Strontia in caustic solution	All iron fitted	Iron disc	Iron ring
Sulphide of hydrogen	All bronze	Bronze disc	Hemp
Sulphite of sodium (hot)	All iron fitted	Iron disc	Iron ring
Sulphuric acid concentrated	All iron fitted	Iron disc	Hemp
Sulphuric acid common	All bronze	Bronze disc	Bronze ring
Sulphurous acid concentrated	All bronze	Bronze disc	Hemp
Sulphurous acid, diluted	All bronze	Bronze disc	Hemp
Tar (hot)	All iron fitted	Iron ball	Iron ring
Tannic acid	All bronze	Bronze disc	Hemp
Toluol	Standard bronze fitted	Bronze disc	Hemp
Turpentine oil	All iron fitted	Iron disc	Iron ring
Vegetable oil	All iron fitted	Iron disc	Iron ring
Vinegar	All bronze	Bronze disc	Hemp
Wine	All bronze	Bronze disc	Bronze ring
Wood alcohol	Standard bronze fitted	Bronze disc	Hemp
Water (hot or cold)	Standard bronze fitted	Rubber or bronze disc	Hydraulic
Water containing sulphur	Standard bronze fitted	Bronze disc	Hydraulic
Water containing some tar and ammonia	All iron fitted	Iron disc	Iron ring
Wood pulp	Standard bronze fitted	Special bronze Ball valve pump	

COLORIMETRIC ESTIMATION OF GOLD IN CYANIDE SOLUTION

Take approximately 1,000 cc. of solution in a tight-stoppered jar (A quart Mason fruit jar is convenient).

Add saturated solution of NaCy to bring the solution to be tested up to about 0.1 per cent NaCy.

Add 2 drops of lead acetate. (Clear saturated solution).

Add a pinch of zinc dust. (Approx. 2 grams).

Shake well for about two minutes.

Pour into a large evaporating dish.

Settle and decant clear solution.

Add 10 cc. aqua regia and evaporate nearly to dryness

Take up in 2 cc. conc. hydrochloric acid.

Pour into a small test tube and cool thoroughly. (Important).

The tube should be about 3 to 4 inches long and not over three-eight inch diameter.

Add a few drops of fresh, saturated, stannous chloride solution.

The presence of gold will be indicated by a purplish ring at point of contact or by a purplish tinge throughout, if the tube is shaken.

The whole operation may be performed over a spirit lamp or similar flame and does not take over five minutes. The presence of as little as 0.02 dwt. gold per ton of solution is very plainly shown.

ESTIMATION OF SILVER IN CYANIDE SOLUTON

A few drops of a 10 per cent solution of sodium sulphide added to 25 or 50 cc. of the solution to be tested, gives a pure white precipitate of zinc sulphide in the absence of silver. The precipitate becomes brownish in the presence of silver, and the depth of color is a very close indication of the amount present.

The presence of the usual small amounts of lead in the solutions does not affect the result appreciably.

INDEX

A. B. C. Air Filters, 129.
Air Clarification, 122
Air Filters, A. B. C., 129.
    Clenworth, Wheal & Co, 129
    Operating Data, 314.
Air Washer, 130, 135.
    Sturtevant, 135
Almy and Lewis, 17.
Alundum Cones, 188.
American Continuous Filter, 254
    H_2O Grease Extracting Feed Water Filter, 180.
    Oil Filter, 167.
Anderson Moisture Expeller, 45.
    Oil Expeller, 184.
    Pressure Oil Filters, 167.
    Steam and Oil Separator, 181.
Area of Filters for Various Rates of Filtration, 360.
Automatic Continuous Screw Press, 43
Average Weights of Materials, 359.

Bag Filters, 202.
Bag Washer, 350.
Bergfeld Filter, 189.
Bird-Save-All, 35.
Blackburn-Smith Feed Water Filter, 61.
Blackburn-Smith Grease Extractor, 176.
Boiler Compounds, 63.
Box Presses, 156.
Bruna Filter, 281.
Buchner Funnel, 187.
Buflovak Vertical Filter, 225.
Burt Filters, 226.
Burt Rapid Cyanide Filter, 226.
Burt Revolving Filter, 226-230.
Burt Revolving Filters, Operating Data, 318-319.
Burt Unit Filter, 168.
By-Products Recoveries Dust Collectors, 122.

Cage Presses, 157.
Capacities of Cylindrical Vessels, 361.
Carbons, Decolorizing, 290.
Centrifugal Clarification, 112.
Centrifugal Force Formulas, 362.
Centrifugal Machines, 96, 186.
Centrifugals, Capacities, 311.
Centrifugals, Data Sheet, 200.
Centrifugals, De Laval, 97.
Centrifugals, Elmore Continuous, 103.
Centrifugals, Fletcher, 108.
Centrifugals, Resines, 106.
Centrifugals, Tolhurst, 116.
Centrifuge, Sharples Super, 109.
Centrifuges, Operating Data, 310
Cheese, 145.
Chemical Filters, Data Sheet, 199.
Clarification, Air, 122.
    Centrifugal, 112.
Classifier, Dorr, 50.
    Dorr Bowl, 52.
    Dorr Multideck, 53
Clark Dust Collectors, 126.
Clenworth, Wheal & Co. Air Filters, 129.
Cloth Washer, 350.
Coagulant Feeders, 331.
Coagulants, 282, 305.
Colorimetric Determination of Gold, 372.
Compressors, 349
Continental Filter, 83.
Continental Gravity Filter, 78
Continuous Centrifugal, Elmore, 103
    Filter, American, 254.
    Filter, Glamorgan, 264.
    Filtering Machine, Louisville, 46.
    Filter, Oliver, 265.
    Filter, Portland, 270.
    Rotary Filter, Zenith, 274.
    Screw Press, Automatic, 43.
Cottrell System, 138.
Cross Oil Filter, 169.
Cummings Filter, 67.
Curb Presses, 162.

Daisy Oil Filter, 172.
Danek Filter, 234.
Data Sheet, Centrifugals, 200
    Chemical Filters, 199.
    Dust Problems, 200.
    Feed Water Filters, 198.
    Water Filters, 196.
Decolorizing Carbons, 290.
De Laval Centrifugal, 97.
    Oil Purifiers, 97.
Deoleizers, 182.
Desk Cooler, 133.
Dewaterer, Zenith Rotary Hopper, 41.
Dorr Bowl Classifier, 52.
    Classifier, 50.

Multideck Classifier, 53.
Thickener, 336.
Dorrco Pump, 339.
Drain-Off Filters, 203.
Dust Collectors, By-Products Recoveries, 122.
Clark, 126.
Reverse Nozzle, Dry, 122
Sturtevant, 136.
Taylor Milliken, 125.
Zenith, 136.
Dust Problems, Data Sheet, 200.

Elmore Continuous Centrifugal, 103.
Erie Oil Filter, 173.
Expeller, Anderson Oil, 184.
Anderson Moisture, 45.
Louisville Continuous Moisture, 48.
Expellers, Oil, 166.
Extractor, Blackburn-Smith Grease, 176.
Grease, 180.
Piece Goods, 108.
Oil, 166.
Textile, 110.

False-Bottom Tanks, 49.
Feed Water Filter, American H_2O Grease Extractor, 180.
Feed Water Filters, Data Sheet, 198.
Feed Water, Treatment of, 63.
Filter Aid Recovery, 352.
Filter Aids, 282, 288.
Filter Media, 202.
Cotton, 295.
Monel Metal, 299.
Supports for, 296
Wool, 300.
Filter Medium, 2.
Rates of Flow through, 329.
Filter Press Operating Data, 315.
Filter Press Pumps, 340.
Filtration, Ancient, 26.
Definition of, 1.
History of, 26.
Medieval, 28.
Modern, 30.
Principles of, 1.
Ultra, 25.
Filtros, 259, 293.
Filtros Wheel, 259.
Fletcher Centrifugals, 108.
Flow of Water in New Pipes, 358.
Formula, Centrifugal Force, 362.
Poiseule's, 21.
Rate of Flow, 17, 22.

Gas Filters, 121.
Glamorgan Continuous Filter, 264.
Single Unit Filter, 280.
Gooch Filter, 187.
Gravity Filters, 56, 78, 86, 90.
Gravity Water Filters, Sizes, Capacities, Weights, 304.

Hatsch, 1.
Hendrix Combination Agitator and Filter, 237.
History of Filtration, 26.
Hodkinson Open Gravity Filter, 58.
Horizontal Filter Pressure, 74, 85.
Horsepower of Engine, 368.
Humidifiers, Natural, 133.
Hungerford and Terry Filters, 73.
Hydraulic Presses, 140.
Cheese, 145
Olive Oil Press, 154.
Presses, Operating Data, 314.
Racks, 145.

Industrial Single Unit Filter, 280.
International Filters, 74

Jewell Filter, 84.
Gravity Filter, 79.
Modified Filter, 79.

Karl Kiefer Filters, 203.
Kelly Filter, 238.
Filters, Data, 321.
Presses, Operating Data, 321.
Keystone Pressure Filter, 88.
Knuckle Joint Press, 140.

Laboratory Centrifuges, 190.
Filter, Vallez, 192.
Filters, 187.
Open Tank Filter, Zenith, 194.
Report Sheet, 201.

Light Filters, 138.
Louisville Continuous Filtering Machine, 46.
  Continuous Moisture Expeller, 48.

Merrill Process, Data, 328.
Mineral Oil Filtration, 186
Mixing Tanks, 353.
Modified Jewell Filter, 79

Natural Humidifiers, 133.
New York Continental Jewell Filters, 77.
New York House Filter, 81.
New York Sectional Wash Gravity Filter, 78, 82.
Norblo Suction Filter, 127.
Nutche Filter, 203.

Oil Expeller, Anderson, 184.
Oil Expellers, 166.
Oil Extractors, 166.
Oil Filter, American, 167.
  Anderson Pressure, 167.
  Cross, 169.
  Daisy, 172.
  Data, 315.
  Erie, 173.
  Operating Data, 315.
  Sims, 178.
  Warden, 171.
Oil Filters, 166.
Oil Filtration, Vegetable and Mineral, 186.
  Press, Hydraulic Olive, 154.
  Purifiers, De Laval, 97.
  Separator, Anderson Steam and, 181.
Oleite, 182.
Oliver Continuous Filter, 265.
  Sand Table Filter, 38.
Open Gravity Filters, 56.
  Hodkinson, 58.
Open Tank Filters, Data, 323.
  Zenith, 250.
Operation of Recessed or Plate Filters, 220.

Pasteur Filter, 189.
Permutit Zeolite Softener, 91.
Perrin Wood Pulp Filter, 215.
Philippe Filters, 234.
Pittsburgh Filters, 85.
Plate and Frame Presses, 207.
Platen, 150.
Plate Presses, 140.
Poiseule's Formula, 21.
Portland Continuous Filter, 270.
Pot Presses, 150
Precipitates, Structure of, 8-13, 15-17
Pressure Roller Unit, 279.
Pressure Water Filters, 60.
Principles of Filtration, 1.
Pulp Washers, 351.
Pump Fitting Materials, 370.
Pumps, Filter Press, 340.
  Suction Filter, 343.

Rack, 145, 152.
Radio Filter, 206.
Rate of Flow, Formula, 17, 22.
Recessed Plate Presses, 208.
Refinite Water Softener, 92.
Resines Centrifugals, 106.
Roberts Filters, 90.
Ross Water Filter, 176.
Rotary Filters, 254.
  Operating Data, 327.
  Vallez, 246.
  Zenith, 274.

Sand Table Filter, Oliver, 38.
Saturated Steam, Properties, 363.
Save-All, Bird, 35.
Screw Press, 140.
Semi-Commercial Filters, 191.
Separator, Anderson Steam and Oil, 181.
Sharples Super-Centrifuge, 109.
Sims Oil Filter, 178.
Single Unit Filter, Glamorgan, 280.
  Industrial, 280.
Slime Plants, Details, 326.
Softeners, 91, 93.
Sperry, 21.
Square Filter Presses, Data, 316-317.
Strainers, 61, 73, 87, 349.
Sturtevant Air Filters, 135.
  Air Washer, 135.
  Dust Collectors, 136.
Suction Filter Pumps, 343.
Sweetland Filters, 242.
  Presses, Operating Data, 322.

Tanks, False Bottom, 49.
Taylor Milliken Dust Collector, 125.
Textile Extractors, Data, 314.
Tolhurst Centrifugals, 116.
Tray Filter, 205.

Ultra-Filtration, 25.
Unglazed Porcelain Filters, 188
Useful Information, 357.

Vacuum Enclosed Tank, 366.
Vallez Filters, 246.
    Data, 322.
    Operating Data, 322.
Vallez Laboratory Filter, 192.
Vater Water Softening System, 84.
Vegetable and Mineral Oil Filtration, 186.
Vertical Filters, Pressure, 74, 88, 89, 90.

Warden Oil Filter, 171.
Warren Gravity Filter, 80.
Water Filters, Blackburn Smith Feed, 61.
    Data Sheet, 196.
    Gravity, 56.
    Operating Data, 301.
    Pressure, 60.
    Ross, 176.
Water Passing over Weirs, 360.
Water Pressure Filters, Data, 305.
Wire Gauge Standards, 369.
Wooden Plate and Frame Filters, 219.
Wood's Machine, 39.
Worthington Press, 146.

Zeit Filters, 205.
Zeolites, 91-92, 286, 308.
Zenith Dust Collector, 136.
    Laboratory Open Tank Filter, 194.
    Open Tank Filters, 250.
    Rotary Filter, 274.
    Rotary Hopper Dewaterer, 41.

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